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CONTENTS

No. 1 MARCH 1956

P. VENNING. Radiological studies of variations in the segmentation and ossification of the digits of the human foot. I. Variation in the number of phalanges and centers of ossification of the toes. Ten figures	1
DAVID B. ALLBROOK. Changes in lumbar vertebral body height with age	35
STANLEY M. GARTLER, I. LESTER FIRSCHEIN AND THEODOSIUS DOBZHANSKY. A chromatographic investigation of urinary amino-acids in the great apes. Six figures	41
RICHARD W. YOUNG. The measurement of cranial shape. Four figures	59
M. R. DRENNAN. Note on the morphological status of the Swanscombe and Fontéchevade skulls. Four figures	73
ALPHONSE RIESENFELD. Multiple infraorbital, ethmoidal, and mental foramina in the races of man	85
STANLEY MARION GARN, SAMUEL SELBY AND MARY R. CRAWFORD. Skin reflectance studies in children and adults. Four figures	101

Reviews:

E. LLOYD DuBRUL AND HARRY SICHER. The adaptive chin. <i>Reviewed by</i> Wilfrid T. Dempster	119
J. M. TANNER. Growth at adolescence. <i>Reviewed by</i> Stanley Marion Garn	120
T. L. SMILEY. Geochronology, with special reference to Southwestern United States. <i>Reviewed by</i> Erik K. Reed	122
J. S. WEINER. The Piltdown forgery. <i>Reviewed by</i> Loren C. Eiseley ...	124
FRED WENDORF, ALEX D. KRIEGER AND CLAUDE C. ALBRITTON. With a description of the skull by T. D. Stewart. The Midland discovery. <i>Reviewed by</i> Robert F. Heizer	126

No. 2 JUNE 1956

P. VENNING. Radiological studies of variation in the segmentation and ossification of the digits of the human foot. Variation in length of the digit segments correlated with difference of segmentation and ossification of the toes. Two figures	129
BERTRAM L. HANNA. Colorimetric estimation of the pigment concentration in hair of various color grades. One figure	153

LOIS W. MEDNICK AND S. L. WASHBURN. The role of the sutures in the growth of the braincase of the infant pig. Six figures	175
ELIHU LEON SCHUMAN AND REIDAR FAUSKE SOGNNÆS. Developmental microscopic defects in the teeth of subhuman primates. Twenty-three figures	193
BRUCE CHOWN AND MARION LEWIS. The blood group genes of the Cree Indians and the Eskimos of the Ungava district of Canada	215
THOMAS MURPHY. The pterion in the Australian aborigine. Five figures ...	225
G. VAN WAGENEN AND H. R. CATCHPOLE. Physical growth of the rhesus monkey (<i>Macaca mulatta</i>). Thirteen figures	245
R. T. SIMMONS, J. J. GRAYDON, N. M. SEMPLE AND D. R. SWINDLER. A blood group genetical survey in West Nakanai, New Britain	275
MARGARET ANDERSON, MARIE BLAIS AND WILLIAM T. GREEN. Growth of the normal foot during childhood and adolescence. Length of the foot and interrelations of foot, stature, and lower extremity as seen in serial records of children between 1-18 years of age. Five figures	287
WILFRID EDWARD LE GROS CLARK. Viking Fund Medalist for 1955	309
<i>Memorium</i> : POMPEO BENJAMIN CANDELA	315
<i>Brief Communication</i> :	
HENRI VALLOIS. The pre-mousterian human mandible from Montmaurin. Two figures	319
<i>Reviews</i> :	
L. CABOT BRIGGS. The stone age races of Northwest Africa. <i>Reviewed by</i> Charles E. Snow	325
S. IDELL PYLE AND NORMAND L. HOERR. Radiographic atlas of skeletal development of the knee. A standard reference. <i>Reviewed by</i> Stanley M. Garn	327
EARNEST A. HOOTON AND C. WESLEY DUPERTUIS. The physical anthropology of Ireland. With a section on the West Coast Irish females. <i>Reviewed by</i> Marcus S. Goldstein	329
ERWIN H. ACKERKNECHT AND HENRI VALLOIS. François Joseph Gall et sa collection. John D. Davies. Phrenology: Fad and science. A 19th century American crusade. <i>Reviewed by</i> Lucile E. Hoyme ...	334
A. C. BURTON AND O. G. EDHOLM. Man in a cold environment. Loren D. Carlson. Man in cold environment: A study in Physiology. <i>Reviewed by</i> Paul T. Baker	337
<i>Book Notes</i>	341
THE AMERICAN ASSOCIATION OF PHYSICAL ANTHROPOLOGISTS. Proceedings, abstracts, and list of members	349

No. 3 SEPTEMBER 1956

DONALD STANLEY MARSHALL AND CHARLES ERNEST SNOW. An evaluation of Polynesian craniology. Two figures	405
EDWARD E. HUNT, JR. AND EUGENE GILES. An evaluation of the Photo-Metric camera. Two figures	429

CONTENTS

V

FRED P. THIEME, CHARLOTTE M. OTTEN AND H. ELTON SUTTON. A blood typing of human skull fragments from the Pleistocene	437
WILLIAM S. POLLITZER. The Henshaw blood factor in New York City Negroes	445
G. T. ASHLEY. A comparison of human and anthropoid mesosterna. Seven figures	449
C. ARAMBOURG AND P. BIBERSON. The fossil human remains from the Paleolithic site of Sidi Abderrahman (Morocco). Nine figures	467
AIMO V. RANTANEN. On the frequency of the missing and peg-shaped maxillary lateral incisor among Finnish students. Two figures	491
STANLEY M. GARN AND RICHARD W. YOUNG. Concurrent fat loss and fat gain. Two figures	497
ALPHONSE RIESENFELD. Shovel-shaped incisors and a few other dental features among the native peoples of the Pacific	505
<i>Brief Communication:</i>	
S. ZUCKERMAN. Sagittal lines and crests	523
<i>Reviews:</i>	
FRANK LORIMER. Culture and human fertility. A study of the relation of cultural conditions to fertility in non-industrial and transitional societies. <i>Reviewed by</i> Clyde Kluckhohn	527
WILLIAM L. THOMAS, JR. Yearbook of Anthropology. <i>Reviewed by</i> Bernice A. Kaplan	533
<i>Book Notes</i>	537

No. 4 DECEMBER 1956

BENTLEY GLASS. On the evidence of random genetic drift in human populations	541
MELVYN J. BAER. Dimensional changes in the human head and face in the third decade of life. Four figures	557
A. MANUILA. Distribution of ABO genes in eastern Europe. Two figures ...	577
ANN L. MERZ, MILDRED TROTTER AND ROY R. PETERSON. Estimation of skeleton weight in the living	589
E. H. ASHTON AND S. ZUCKERMAN. The base of the skull in immature hominoids. Three figures	611
P. B. SAWIN AND D. D. CRARY. Morphogenetic studies of the rabbit. XVI. Quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth. Two figures	625
MILDRED TROTTER, OLIVER H. DUGGINS AND FRANK M. SETZLER. Hair of Australian aborigines (Arnhem Land)	649
JØRGEN BALSLEV JØRGENSEN AND FLEMMING QUADE. External cranial volume as an estimate of cranial capacity. Three figures	661

Reviews:

THEODOSIUS DOBZHANSKY. Evolution, genetics, and man. <i>Reviewed by</i> Joseph B. Birdsell	665
W. C. OSMAN HILL. Primates (comparative anatomy and taxonomy). I. Strepsirhini. II. Haplorhini: Tarsioidea. <i>Reviewed by</i> William L. Straus, Jr.	668
G. H. R. VON KOENIGSWALD. Begegnungen mit dem Vormenschen. <i>Re-</i> <i>viewed by</i> Richard W. Young	673
<i>Book Notes</i>	675

RADIOLOGICAL STUDIES OF VARIATIONS IN THE SEGMENTATION AND OSSIFICATION OF THE DIGITS OF THE HUMAN FOOT

I. VARIATION IN THE NUMBER OF PHALANGES AND CENTERS OF OSSIFICATION OF THE TOES

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TEN FIGURES

INTRODUCTION

The skeletal structure of the human great toe, as measured by the number of phalanges into which it is divided and the number of centers from which these segments ossify, appears to be almost constant. The skeletal structures of the 2nd, 3rd, 4th and 5th toes, however, vary with respect to both these characteristics. Each of these toes may consist of either two or three phalanges. The 2nd, 3rd and 4th commonly have three phalanges and only rarely two, while among 5th toes both types occur with nearly equal frequency in Europeans. In addition the number of centers of ossification that develop in the middle phalanx of toes with three phalanges and in the terminal phalanx of toes with two phalanges varies. An analysis is presented of these skeletal differences observed in a collection of radiographs of the feet of children and adults of both sexes.

LITERATURE

The first systematic studies of these skeletal variations were made by Pfitzner (1890, 1896). Before Pfitzner's observations anatomists believed that fusion during adult life of the two most distal of the three phalanges of the 5th toe

accounted for the occurrence of two phalanges on this toe. This fusion was said to be brought about either by disuse of the terminal joint or by inflammatory changes produced by footwear. Pfitzner (1890) showed that the form of segmentation into two or three phalanges was already established in the cartilaginous skeleton of fetuses and children with about the same frequency as in adults. Nevertheless Pfitzner continued to regard the terminal phalanx of 5th toes with two phalanges as the product of fusion between the terminal and middle phalanges of the three phalanged form, which he presumed occurred early in ontogeny.

Pfitzner observed that the middle phalanges on the 2nd, 3rd and 4th toes were of two kinds, one long and slender, the other short and squat. This latter, reduced, form he found to be commoner on the more lateral toes and to be the only type occurring on the 5th toe. He found that the presence of this short form on the 2nd, 3rd and 4th toes was frequently associated with the occurrence of two phalanges on the 5th toe. He reported that both the short middle phalanges and the occurrence of two phalanges on the 5th toe were more common among females. Pfitzner regarded the reduction of the number of phalanges of the 5th toe as the end-result of the progressive reduction of the middle phalanx of this toe.

In a further study Pfitzner (1896) gave the frequencies with which two phalanges were found on each of the 2nd, 3rd, 4th and 5th toes in large samples of adult post-mortem material of each sex. In no foot was a two phalanged toe, other than that of the 1st, found medial to a toe with three phalanges. Pfitzner also made observations on the ossification of the phalangeal skeleton. These were extended by Hasselwander ('03) in a more detailed study of the ossification of the feet of fetuses and children, using both radiological and dissected material.

He found that the number of centers and form of ossification of the middle phalanges varied. On the short middle phalanges, most commonly found on the more lateral toes, the epiphysis was usually either absent, or represented by

a pseudo-epiphysis due to the invasion of the unossified epiphyseal cartilage by a localized outgrowth of bone from the diaphysis. The centers of ossification of terminal phalanges of 5th toes with two phalanges were described by Hasselwander in terms of their supposed homologues among the centers of ossification in toes with three phalanges. Thus the proximal center was referred to as the "middle phalanx" center, and the distal center as the "terminal phalanx," or, sometimes, the "end-cap" (*tuberositas ungricularis*) center. Apart from such questions of interpretation, the forms of ossification described by Hasselwander have, in general, been confirmed by the present study.

Unfortunately, few of Pfitzner's or Hasselwander's conclusions that are based on quantitative data are amenable to statistical tests of significance. An exception concerns Pfitzner's data relating to the sex difference in the occurrence of two phalanges on the 5th toe. This difference was found not to be significant at the 5% level. For this reason many of the observations of these investigators have been repeated in the present study.

Trolle ('48) investigated the incidence of toes with only two phalanges among a large sample of fetuses. He found that from 12 weeks onwards the cartilaginous skeleton of the toes had differentiated sufficiently for the number of phalanges to be recognized. In his material the frequency of occurrence of 5th toes with two phalanges after this age was no different in the younger than in the older embryos.

Adachi ('05) and Hasebe ('12a) have studied the frequency of the presence of only two phalanges among Japanese. According to Straus ('27) the two-phalanged condition in the 5th toe has been observed also among Terra del Fuegan Indians, American Negroes, African Hottentots, and Egyptians. Venning ('54) reported a significant sib-sib correlation with respect to the number of phalanges in the 5th toe.

Table 1 shows the frequencies with which only two phalanges have been observed on the small toes by various investigators. Two phalanges were found more commonly

TABLE 1
The frequencies of toes with two phalanges reported by different investigators

INVESTIGATOR	MATERIAL	METHOD	SEX	NO. OF FEET	2ND TOE		3RD TOE		4TH TOE		5TH TOE	
					No.	%	No.	%	No.	%	No.	%
Pfitzner (1890)	European fetuses and children	Dissection	Both	91	0	—	0	—	0	—	37	40.7
Pfitzner (1896)	European adults	Dissection	Male	557	—	—	—	—	—	—	198	35.5
			Female	263	—	—	—	—	—	—	108	41.1
			Both	838	3	0.4	4	0.5	13	1.6	310	37.0
Hasselwander ('03)	European fetuses and children	Dissection and X rays	Both	172	0	—	0	—	2	1.1	83	47.1
Hasselwander ('10)	European children and adults	Dissection and X rays	Male	143	2	1.4	3	2.1	7	4.9	53	37.1
			Female	113	0	—	0	—	4	3.5	52	46.0
			Both	256	2	0.8	3	1.2	11	4.3	105	41.0
Adachi ('05)	Japanese adults	Dissection and X rays	Both	97	—	—	—	—	3	3.0	80	80.4
Hasebe ('12)	Japanese adults	Dissection	Male	180	0	—	0	—	18	10.0	130	72.2
			Female	80	0	—	0	—	2	2.5	61	76.3
			Both	260	0	—	0	—	20	7.7	191	73.5
Trolle ('48)	European fetuses	Dissection	Both	370	0	—	1	0.3	2	0.6	137	36.0

among females by all the investigators who give figures for each sex separately, but in each case the differences are not significant at the 5% level. The difference between the frequencies found in Europeans and Japanese are striking.

Most of the authors quoted speak of the terminal phalanx of the two phalanged condition as being produced by the "fusion" of the terminal and middle phalanges. They thus regard the two phalanged condition as being derived, in some sense, from the three phalanged condition, though whether this derivation is thought to occur in ontogeny is not always clear.

The view was held by Pfitzner (1896), Hasselwander ('03) and subsequently by Straus ('27) and Wood Jones ('44) that the two phalanged form of the skeleton represents a new phylogenetic process involving retrogression of the middle phalanges and tending to reduce the post-axial digits of the foot. Wood Jones regards this change as adaptive to the requirement of stability rather than propulsive ability in this side of the foot.

MATERIAL

The present material consists of the dorsi-plantar x-rays of both feet, taken under standard radiographic conditions, of 2316 individuals. Table 2 shows the age and sex distribution of these samples.

The adult sample containing persons of 16 years and over consisted of the following groups of subjects:

- (a) All the staff and students of this department available over a certain period (300).
- (b) All the student nurses at University College Hospital available during certain duty periods (25).
- (c) All the sailors available at a naval establishment at Portsmouth (42).
- (d) All persons over 45 years attending the Physical Medicine Department of University College Hospital as out-patients on particular days who were not suffering from a complaint associated with their feet. This group was selected partly to increase the represen-

tation of the older age groups and partly as additional control for the next group (32).

- (e) All persons attending the National Orthopaedic Hospital as out-patients for treatment of Hallux Valgus over a certain period who could be persuaded to attend this department for x-ray. This group has only been included after a comparison with persons from the previous groups of comparable age and sex distribution had shown no significant differences with respect to those characteristics of the phalangeal skeleton which are the subject of this study (100).

TABLE 2
Material analyzed with respect to sex and age

AGES	MALES	FEMALES	TOTAL
<i>yrs.</i> ¹			
4	26	29	55
5	92	80	172
6	81	93	174
7	88	85	173
8	63	79	142
9	71	59	130
10	99	89	188
11	87	83	170
12	100	117	217
13	102	117	219
14	95	82	177
Sub-total children	904	913	1817
16-19 ²	102	80	182
20-29	76	98	174
30-39	30	27	57
≥ 40 ³	18	68	86
Sub-total adults	226	273	499
Total	1130	1186	2316

¹ Age at previous birthday.

² The numbers in this age group are not evenly dispersed.

The mean ages are: Males 18.3 years
Females 18.5 years
Total 18.4 years

³ Mean ages in this group: Males 49.4 years. S.D. 8.84 years
Females 50.0 years. S.D. 7.73 years.

Fusion between the different centers of ossification of the separate phalanges had taken place in all the people of this adult sample, except in two males aged 18 years in whom fusion of the epiphyses of the middle phalanges was incomplete on some toes.

The sample of 1817 children consisted of all the pupils attending a group of Infant, Junior and Secondary Modern Schools in Middlesex, x-rayed during May 1950.

The x-rays of both samples were taken in the course of an investigation into the anatomy of Hallux Valgus (Hardy and Clapham, '51, '52), with the exception of 120 of the students and staff of this department who were x-rayed in the course of an unpublished investigation by Dr. W. A. Fell, by whose permission they have been used in the present survey.

PROCEDURE

Classification according to types of segmentation and ossification

Each of the radiographs of the adult and child collections were examined to determine the number of phalanges present on each of the small toes. In the case of adults and the older children in whom the different centers within the phalanges had fused this classification presented no particular difficulty. Errors of classification among these are unlikely to have occurred except in a few cases of gross foreshortening of the image of the distal part of the skeleton of some toes.

In the case of children in whom the centers of ossification remained separate such a classification depends upon distinguishing between the several forms of ossification which occur, and determining to which of the two kinds of segmentation each of these forms belongs. In the case of the 5th toe such distinctions are not obvious, and a careful study of the radiographs, especially those in which partial fusion between centers could be seen, was necessary.

On all the radiographs the proximal phalanges could be identified without doubt on all toes, nor was any exception

observed in the number of centers from which these phalanges ossified. These were a primary center for the shaft and an epiphysis at the proximal end.

On toes with three phalanges no exceptions were found in the ossification of the terminal phalanx which in every case develops from two centers. On the 2nd, 3rd and 4th toes these two centers may confidently be described as a primary center for the distal part of the phalanx and an epiphysis at the proximal end. On the 5th toe, however, the more proximal of the two centers was not uncommonly the larger and in at least some cases the first to ossify. In such cases this center cannot appropriately be described as an epiphysis.

Among the middle phalanges the different forms of ossification described by Hasselwander were recognized. These were (1) two centers of ossification; a primary center and an epiphysis at the proximal end. (2) A single primary center with no sign of epiphyseal ossification. (3) A single primary center, but with a so-called pseudo-epiphysis formation at the proximal end. The degree of notching by which these pseudo-epiphyses are partially separated from the distal part of the phalanx varied continuously between the extremes of complete separation and complete absence. Like the ordinary separate epiphyses these pseudo-epiphyses become obliterated by fusion during development.

On toes with two phalanges two forms of ossification of the terminal phalanx were recognized. These were (1) two centers, of which the more proximal is usually the longer, and at least in some cases on the 5th toe apparently the first to ossify; (2) a single center. This latter form was observed only on the 5th toe. There is, of course, always a question whether such single centers are not due either to the fusion of two centers, or to the delay in ossification of a second center as Hasselwander presumed. In the present material, however, these single centers, though rare, were observed to occur among the younger children, apparently occupying all the available phalanx and showing no visible signs of recent fusion. Furthermore, they occurred on feet

in which all other centers were well ossified, and in which no signs of fusion were apparent. For these reasons they have been classified as a distinct form of ossification.

With a few doubtful exceptions, which will be discussed below, the types of ossification described were the only ones observed in the collection of radiographs. For convenience of description these types will henceforward be identified according to the number of centers of ossification developing distal to the proximal phalanx, as follows:

- Type 1. One center: i.e. for the terminal phalanx of toes with two phalanges.
- Type 2. Two centers: i.e. for the terminal phalanx of toes with two phalanges.
- Type 3. Three centers: i.e. two for the terminal and one for the middle phalanx of toes with three phalanges.
- Type 3 +. As for Type 3, except for the existence of a pseudo-epiphyses on the middle phalanx.
- Type 4. Four centers: i.e. two for each of the terminal and middle phalanges of toes with three phalanges.

Thus toes with two phalanges develop from Type 1 or Type 2; while toes with three phalanges develop from Type 3, Type 3 + or Type 4. Figure 1 represents schematically these developmental connections. Figures 2 and 3 show examples of the two and three phalanges among the toes of adult feet. Figures 4, 5, 6 and 7 show examples of the different types of ossification among the toes of children's feet.

For the purpose of the subsequent quantitative analysis of the occurrence of these forms of ossification, Type 3 + is included with Type 3 owing to the difficulty of distinguishing between them in many cases.

Plots of the frequencies with which the different centers of ossification in each phalanx were present and unfused in consecutive yearly age groups of children of each sex, revealed the ages at which ossification and fusion of the centers occurred. It was found that the ages $> 7 < 11$ years in

males and $> 5 < 9$ years in females provided the largest samples in each sex (321 males and 337 females), in which all the centers were ossified but unfused in nearly every case. Each radiograph in these restricted samples was analysed with respect to the number of centers of ossification present on each toe.

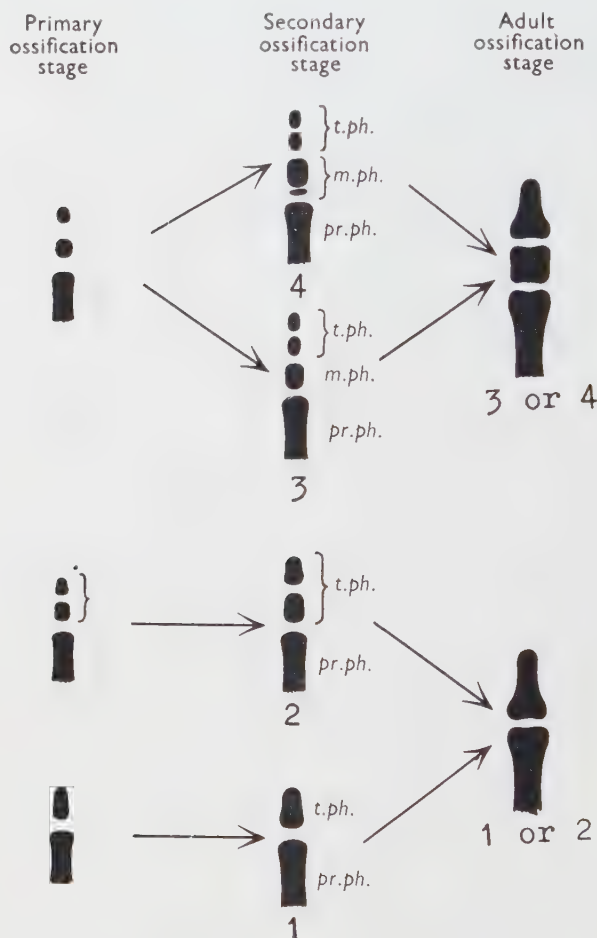


Fig. 1 Schematic representation of the developmental connections between the different types of ossification.

t.ph. = terminal phalanx

m.ph. = middle phalanx

pr.ph. = proximal phalanx.

Possible errors of classification

These are of two kinds: the first due to misclassification among the types described, and the second due to the possible existence of other types of ossification. This latter possibility will be considered first.

There were a few feet in which it appeared that a terminal phalanx of a 5th toe with two phalanges was ossifying from three centers. Figure 8 illustrates the most convincing ex-

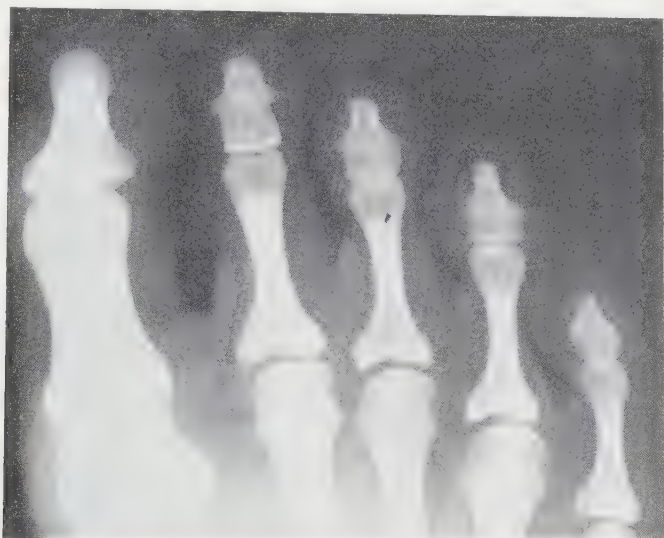


Fig. 2 Right foot female 19 years. Film no. F7. Two phalanges on each toe. The left foot was the same.

ample of this, though even in this case some doubt remains as to whether the proximal of these three centers is involved in fusion, or whether it is the center of a separate middle phalanx. Other cases were seen, typical in all respects of Type 2, except that the proximal center of the terminal phalanx had itself apparently been produced by the fusion of two centers. Figure 9a illustrates an extreme example of this. There remains some doubt, however, whether these appearances are to be correctly interpreted as signs of fusion be-



Fig. 3 Right and left feet female 14 years. Film no. 605.

Right foot: two phalanges on the 3rd, 4th and 5th toes
three phalanges on the 2nd toe.

Left foot: two phalanges on the 4th and 5th toes
three phalanges on the 2nd and 3rd toes.

tween two centers. Figure 9 b shows that the proximal center of the terminal phalanx in Type 2 may ossify in a way not unlikely to produce a dumb-bell appearance during later development. Pfitzner (1890) reported that the cartilage of the terminal phalanx of 5th toes with two phalanges is in some cases more or less divided transversely by a fissure at about one-third of its length from the proximal end. This corresponds to the position of the apparent line of fusion seen in some of these centers, which may therefore be due to a defect in the cartilage. In this study all instances of three centers distal to the proximal phalanx have been classified as Type 3. If this additional type of ossification of the terminal phalanx does occur it is certainly rare and the resulting misclassifications between 5th toes with two or three phalanges will have been few.

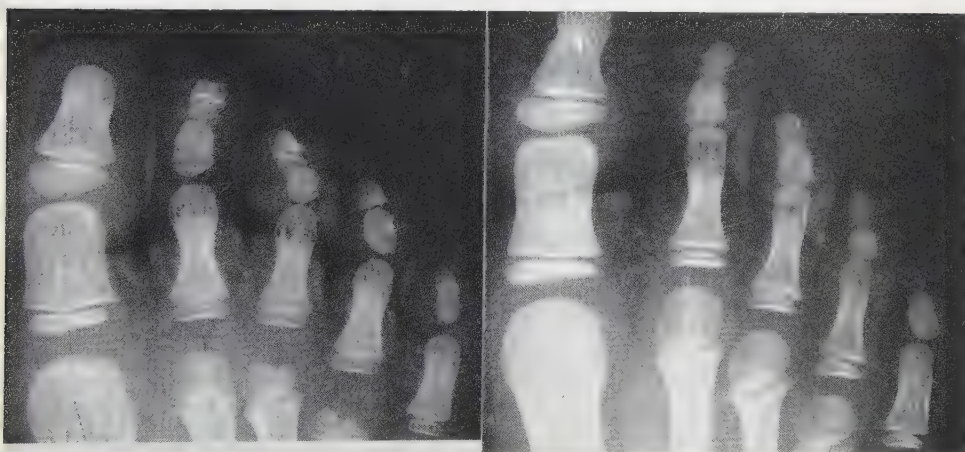


Fig. 4a and 4b (a) Right foot male 4 years. Film no. 520.
 Showing the following types of ossification:
 2nd and 3rd toes — Type 3
 4th toe — Type 2
 5th toe — Type 1 or 2.
 (b) Right foot male 8 years. Film no. 1311.
 2nd toe — Type 3 +
 3rd and 4th toes — Type 3
 5th toe — Type 1



Fig. 5a and 5b (a) Left foot male 5 years. Film no. 308.
 2nd toe — Type 4
 3rd and 4th toes — Type 3
 5th toe — Type 2 with usual relative lengths
 of the two centers of the terminal
 phalanx.
 (b) Right foot male 13 years. Film no. 1689.
 5th toe Type 2 with proximal center of the terminal pha-
 lanx smaller than the distal.

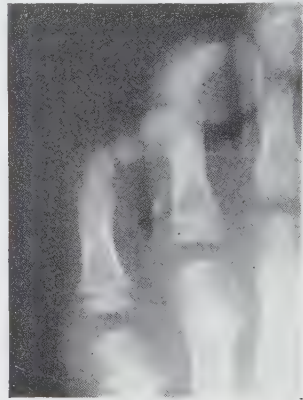


Fig. 6a and 6b (a) Left foot female 7 years. Film no. 43.
 2nd toe — Type 4
 3rd toe — Type 3 +
 4th and 5th toes — Type 3, with the proximal centers
 of the terminal phalanx smaller
 than the distal.
 (b) Right foot male 6 years. Film no. 96.
 5th toe Type 3 with the proximal center of the terminal
 phalanx larger than the distal.

A more common source of possible error arises, as can readily be seen from figure 1, if Type 3 or Type 4 is classified as Type 2, due either to fusion between centers having taken place, or to a center being not yet ossified. There are however a number of clues which assist in making correct



Fig. 7 Left foot male 13 years. Film no. 1826. 2nd, 3rd, 4th and 5th toes Type 4.



Fig. 8 Left foot male 12 years. Film no. 1611. Apparent fusion taking place between the three centers distal to the proximal phalanx of the 5th toe.

classifications. Firstly, the size of and spacing between the ossification centers on the toe in question, and on the other toes, will generally reveal whether there are centers yet to be ossified. Secondly, the likelihood of fusion having occurred can usually be judged from the appearance of the other toes and from the presence or absence of some vestigial line of fusion in the bone in question. Thirdly, the relative size of the centers in the two and three phalanged toes provide additional evidence. Thus the image of the middle phalanx of

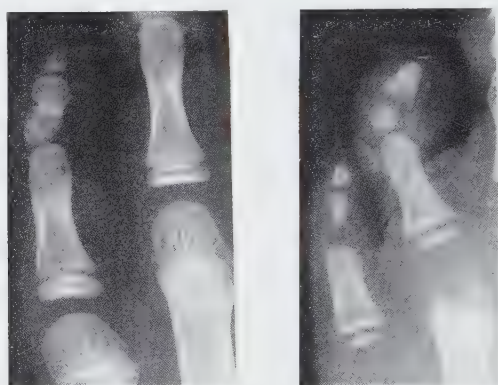


Fig. 9a and 9b (a) Left foot male 10 years. Film no. 1369. Proximal of the two centers distal to the proximal phalanx of the 5th toe, apparently formed by the fusion of two centers.
(b) Left foot male 4 years. Film no. 492. Form of ossification of the 5th toe that might later give rise to the appearance shown in (a).

5th toes occupies on the average in both children and adults about 40% of the sum of the lengths of all bone centers distal to the proximal phalanx. The image of the proximal center of the terminal phalanx in Type 2, with which it might be confused, occupies about 60% of the sum of the length of the two centers of this phalanx (table 3).

With the aid of these criteria it was possible to classify the feet of the children with respect to number of phalanges on the toes with some degree of confidence and to classify the feet represented in the restricted samples of males 7-10

years and females 5-8 years with respect to the number of centers developing in each toe.

Statistical comparisons. The Chi-squared test has been used to compare frequencies. Yates' correction for continuity has been applied when any cell contained five or fewer examples. Values of $P \leq 0.05$ have been taken as showing significant differences.

TABLE 3

Differences in proportional lengths of the centers of ossification distal to the proximal phalanx in 5th toes with two and three phalanges: measured on left feet

SUBJECT	5TH TOES: TYPE 2 OSSIFICATION			5TH TOES: TYPE 3 OSSIFICATION		
	Length of proximal center of terminal phalanx as percentage of total length of terminal phalanx			Length of middle phalanx as percentage of sum of lengths of middle and terminal phalanges		
	No.	Mean	S.D.	No.	Mean	S.D.
Male children						
$\geq 7 < 11$ yrs.	124	61.49	10.80	184	42.34	4.96
Female children						
$\geq 5 < 9$ yrs.	138	62.62	10.70	153	44.27	5.55
Male adults	...	....	....	133	43.41	5.09
Female adults	...	....	....	104	44.36	4.47

RESULTS

A. *The number of phalanges in the toes*

1. *The frequency of toes with two phalanges with respect to age.* The frequency with which two phalanges occurred on the different toes was obtained for each of the eleven consecutive yearly age groups of children, and the five age groups of adults shown in table 2. The frequencies showed no tendency to vary systematically with age in either sex.

Table 4 shows the frequencies of two phalanges on the different toes in the combined child samples and the combined adult samples of each sex. Comparisons of the frequencies in children and adults for the 4th and the 5th toes show no significant differences in either sex. This result confirms the findings of Pfitzner (1890) and Trolle ('48).

TABLE 4

Occurrence of two phalanges in children and adults(Percentages calculated by counting a bilateral occurrence = 1 and a unilateral occurrence = $\frac{1}{2}$)

SAMPLE	NUMBER IN SAMPLE	2ND TOE			3RD TOE			4TH TOE			5TH TOE		
		Bilat.	Unilat.		Bilat.	Unilat.		Bilat.	Unilat.		Bilat.	Unilat.	
			R	L		R	L		R	L		R	L
			%			%			%			%	
Male	Children	—	—	—	6	—	1	18	1	2	333	28	35
	Adults	—	—	—	—	—	—	5	—	—	80	6	8
	Total	1130	—	—	—	6	—	23	1	2	413	34	43
Female	Children	—	—	—	2	1	1	15	2	10	384	21	41
	Adults	1	—	0.37	1	—	—	4	—	1	105	8	19
	Total	1186	1	—	0.08	3	1	19	2	11	489	29	60
Combined sexes		2316	1	—	0.04	9	1	42	3	13	902	63	103

In view of this finding the child and adult samples have been combined in each sex for subsequent analysis of the frequencies of toes with two phalanges.

2. *The relative position in the foot of toes with two and toes with three phalanges.* Table 5 (i) and (ii) show the

TABLE 5

Occurrence of two and three phalanges among the toes of the feet of the combined samples of children and adults:

I. Males; II. Females

I. MALES

					RIGHT FOOT						
					2nd	Three	Three	Three	Three	Two	
Toes					3rd	Three	Three	Three	Two	Two	
					4th	Three	Three	Two	Two	Two	
2nd 3rd 4th 5th					Three	Two	Two	Two	Two	TOTAL	
Left foot	Three	Three	Three	Three	640	34	—	—	—	674	
	Three	Three	Three	Two	43	387	1	—	—	431	
	Three	Three	Two	Two	—	2	16	—	—	18	
	Three	Two	Two	Two	—	—	1	6	—	7	
	Two	Two	Two	Two	—	—	—	—	—	0	
Total					683	423	18	6	0	1130	

II. FEMALES

					RIGHT FOOT						
					2nd	Three	Three	Three	Three	Two	
Toes					3rd	Three	Three	Three	Two	Two	
					4th	Three	Three	Two	Two	Two	
					5th	Three	Two	Two	Two	Two	TOTAL
Left foot	2nd	3rd	4th	5th	Three	Two	Two	Two	Two	Two	
	Three	Three	Three	Three	608	29	—	—	—	—	637
	Three	Three	Three	Two	60	457	2	—	—	—	519
	Three	Three	Two	Two	—	11	14	1	—	—	26
	Three	Two	Two	Two	—	—	1	2	—	—	3
					Two	Two	Two	Two	—	1	1
Total					668	497	17	3	1	1186	

distributions of toes with two and toes with three phalanges in the feet of the combined child and adult samples of each sex. The distributions show that, when both forms of segmentation occur in the same foot, toes with three phalanges are medial to toes with two phalanges. It follows from this

that two phalanges must occur most often in the 5th toes, and with diminishing frequency in the 4th, 3rd and 2nd toes.

3. *The relative frequency of two and three phalanges in the different toes.* The 2nd, 3rd and 4th toes usually have three and only rarely two phalanges. In 5th toes the frequencies of two and three phalanges are more nearly equal, but three phalanges occur more often on both the right and left feet of each sex. The difference is significant in each case.

Males 5th toes right feet: 447 two phals; 683 three phals. $P < 0.001$

Males 5th toes left feet: 456 two phals; 674 three phals. $P < 0.001$

Females 5th toes right feet: 518 two phals; 668 three phals. $P < 0.001$

Females 5th toes left feet: 549 two phals; 637 three phals. $P < 0.02$

4. *Similarity of right and left feet with respect to the number of phalanges on the toes.* Table 5 (i) and (ii) show that the right and left feet of the great majority of individuals of each sex were alike with respect to the number of phalanges on the different toes. Thus among males the feet were alike in 1049 individuals and unlike in 81, and among females the feet were alike in 1082 individuals and unlike in 104. The product-moment correlations between the two sides with respect to the occurrence of two or three phalanges, show that the tendency for the two sides to be alike is highly significant in the case of the 4th and 5th toes of each sex.

Males 1130 pairs of right and left 4th toes $r = +0.917$ $P < 0.001$

Males 1130 pairs of right and left 5th toes $r = +0.858$ $P < 0.001$

Females 1186 pairs of right and left 4th toes $r = +0.732$ $P < 0.001$

Females 1186 pairs of right and left 5th toes $r = +0.850$ $P < 0.001$

5. *Differences between right and left feet with respect to the number of phalanges on the toes.* Table 5 (i) and (ii) show that toes with two phalanges occur unilaterally more often on left than on right feet. Right and left feet, and right and left corresponding toes, may be compared with respect to the frequencies with which each side has fewer phalanges than the other.

Males:	right	feet fewer 35;	left	feet fewer 46.	Difference not significant
Males:	right 4th toes fewer 1;	left 4th toes fewer 2.	Difference not significant		
Males:	right 5th toes fewer 34;	left 5th toes fewer 43.	Difference not significant		
Females:	right	feet fewer 32;	left	feet fewer 72.	$P < 0.001$
Females:	right 4th toes fewer 2;	left 4th toes fewer 11.	$P < 0.05$		
Females:	right 5th toes fewer 29;	left 5th toes fewer 60.	$P < 0.01$		
Both					
sexes:	right	feet fewer 67;	left	feet fewer 118.	$P < 0.001$
Both					
sexes:	right 4th toes fewer 3;	left 4th toes fewer 13.	$P < 0.05$		
Both					
sexes:	right 5th toes fewer 63;	left 5th toes fewer 103.	$P < 0.01$		

Thus in the female sample, and in the male and female samples combined, the differences are significant. In the male sample the differences, though not significant are in the same direction. It may be concluded therefore that toes with two phalanges probably tend to occur more often on left than on right feet.

6. *Differences between males and females and respect to the number of phalanges in the different toes.* Table 5 (i) and (ii) show the frequencies with which two phalanges occur in males and females on the different toes of right feet, left feet, bilaterally and unilaterally. Comparisons of this frequency show no significant differences between the sexes with respect to the occurrence of two phalanges on the 4th toes. In the case of the 5th toe two phalanges occur significantly more often in females on right feet ($\chi^2 = 4.04$ $P < 0.05$), on left ($\chi^2 = 8.30$ $P < 0.01$) and bilaterally ($\chi^2 = 6.33$ $P < 0.02$). The difference between the unilateral frequencies is not significant ($\chi^2 = 2.35$ $P < 0.10$).

B. *The occurrence of the different types of ossification*

1. *The relative position in the foot of toes with different types of ossification.* The distribution of the different types of ossification among the toes of the restricted male ($> 7 < 11$ years) and female ($> 5 < 9$ years) samples were analyzed.

It was found that when more than one type of ossification is present on one foot, types with the greater number of centers are medial to those with a smaller number. Among the 658 children for whom these data are presented there was only one exception (female) to this rule, and this exception was unilateral. In this case Type 4 ossification was present on the 4th toe and Type 3 on the 3rd toe. Figure 10 reproduces the radiograph of this foot. It shows that the terminal phalanges of the two toes in question are syndactylous.



Fig. 10 Left foot female 5 years. Film no. 443. Showing only example of reversal of the medio-lateral order of ossification types among the toes.

2nd toe — Type 4 3rd toe — Type 3 4th toe — Type 4 5th toe — Type 3.

Though no data was collected concerning Type 3 + (pseudo-epiphysis of the middle phalanx), it may be mentioned that, as far as could be ascertained, this type of ossification also conformed, in the great majority of feet, to the positional order described above, i.e. it occurred medial to toes with Type 3, and lateral to toes with Type 4 ossification. Four exceptions were observed: in two children bilaterally, and one child unilaterally Type 3 + was present on the 4th toe and Type 3 on the 3rd, in another child Type 3 + was present on the 3rd toe and Type 3 on the 2nd toe.

The positional order described does not imply that when more than one type of ossification occurred in the same foot that the types present form a continuous consecutive series

mediolaterally. On the contrary it occasionally happens that Types 1 and 3, or 4 and 2 are present on adjacent toes. In those cases the intermediary type of the series is not represented in the foot.

2 *Relative frequencies of the different ossification types on the different toes.* Table 6 shows the frequencies with which the different ossification types occur on the 2nd, 3rd, 4th and 5th toes in each sex and in both sexes combined, of the restricted child samples.

Comparisons of these frequencies show that in the male sample Type 4 is the commonest mode of ossification in the 2nd and 3rd toes, and Type 3 on the 4th and 5th toes. In the female samples Type 4 is the commonest form on the 2nd toe, and Type 3 on the 3rd, 4th and 5th toes. These differences are all significant. In the combined sample Types 3 and 4 occur with about equal frequency on the 3rd toe.

3. *The correlation between toes of the same foot with respect to the types of ossification.* The associations between pairs of toes in the same foot with respect to the types of ossification were analyzed. It was found that the 2nd, 3rd and 4th toes had Type 4 ossification more frequently when the 5th toe of the same foot had three, than when it had two phalanges. The product-moment correlations between the 2nd and 5th, 3rd and 5th, and 4th and 5th pairs of toes in the same feet with respect to the number of phalanges in the 5th toes and the type of ossification (i.e. Type 4, or not Type 4) on each of the other toes show that this association is significant for each pair of toes on both feet of each sex.

Males	321 prs	2nd and 5th toes:	Rt. $r = + 0.219$	$P < 0.05$;
			Lt. $r = + 0.206$	$P < 0.05$;
Males	321 prs	3rd and 5th toes:	Rt. $r = + 0.367$	$P < 0.001$;
			Lt. $r = + 0.388$	$P < 0.001$;
Males	321 prs	4th and 5th toes:	Rt. $r = + 0.276$	$P < 0.01$;
			Lt. $r = + 0.269$	$P < 0.01$;
Females	337 prs	2nd and 5th toes:	Rt. $r = + 0.324$	$P < 0.001$;
			Lt. $r = + .0306$	$P < 0.01$;
Females	337 prs	3rd and 5th toes:	Rt. $r = + 0.386$	$P < 0.001$;
			Lt. $r = + 0.315$	$P < 0.01$;
Females	337 prs	4th and 5th toes:	Rt. $r = + 0.223$	$P < 0.05$;
			Lt. $r = + 0.215$	$P < 0.05$;

Thus the middle phalanx of the 2nd, 3rd and 4th toe develops an epiphysis (Type 4) more frequently when the 5th toe has three than when it has two phalanges.

4. *Similarity of right and left feet with respect to the types of ossification of the toes.* The frequencies with which right and left feet, and right and left corresponding toes, were the same or different with respect to the types of ossification were analyzed. Among males the right and left feet were the same in 257 individuals, and unlike in 64 individuals; among females the feet were the same in 279 cases and different in 58 cases. The product-moment correlations were calculated between right and left corresponding toes; in the case of the 2nd, 3rd and 4th pairs of toes with respect to the occurrence of type 3 or type 4, and in the case of 5th toes with respect to the occurrence Type 2 or Type 3. In each case the tendency for the two sides to have the same type of ossification was found to be highly significant.

Males 321 pairs of right and left 2nd toes: $r = +0.821$, $P < 0.001$

Males 317 pairs of right and left 3rd toes: $r = +0.895$, $P < 0.001$

Males 315 pairs of right and left 4th toes: $r = +0.876$, $P < 0.001$

Males 315 pairs of right and left 5th toes: $r = +0.874$, $P < 0.001$

Females 337 pairs of right and left 2nd toes: $r = +0.975$, $P < 0.001$

Females 336 pairs of right and left 3rd toes: $r = +0.868$, $P < 0.001$

Females 328 pairs of right and left 4th toes: $r = +0.877$, $P < 0.001$

Females 327 pairs of right and left 5th toes: $r = +0.838$, $P < 0.001$

5. *Differences between right and left sides with respect to the type of ossification of the toes.* Table 7 shows the frequencies with which each combination of dissimilar types of ossification occurred on right and left corresponding toes. It will be observed that nearly every case the type with the fewer centers of ossification occurred more often on left than on right feet. Right and left sides have therefore been compared with respect to the frequencies with which each side has fewer centers of ossification than the other, irrespective of the particular combinations of dissimilar types present. These frequencies are shown in the last two rows of table 7 for each

TABLE 7

Occurrences of dissimilar types of ossification on the toes of right and left feet

	MALES					FEMALES					BOTH SEXES				
	2nd toes	3rd toes	4th toes	5th toes		2nd toes	3rd toes	4th toes	5th toes		2nd toes	3rd toes	4th toes	5th toes	
Right type 4: Left type 3	9	13	8	1		7	15	3	—		16	28	11	1	
Right type 3: Left type 4	3	7	4	—		1	7	5	1		4	14	9	1	
Right type 3: Left type 2	—	1	—	11		—	—	1	19		—	1	1	30	
Right type 2: Left type 3	—	—	—	8		—	—	—	7		—	—	—	15	
Right type 3: Left type 1	—	—	—	1		—	—	—	—		—	—	—	1	
Right type 1: Left type 3	—	—	—	—		—	—	—	—		—	—	—	—	
Right type 2: Left type 1	—	—	—	1		—	—	—	2		—	—	—	3	
Right type 1: Left type 2	—	—	—	1		—	—	—	—		—	—	—	1	
Right more centers than left	9	14	8	14		7	15	4	21		16	29	12	35	
Right fewer centers than left	3	7	4	9		1	7	5	8		4	14	9	17	
Right more centers than left	All toes combined	All toes combined		32		All toes combined	All toes combined		37		All toes combined	All toes combined		69	
Right fewer centers than left	All toes combined	All toes combined		20		All toes combined	All toes combined		18		All toes combined	All toes combined		38	

pair of right and left toes, and for right and left feet when the number of centers on all the toes are combined.

In every case, except the 4th toes of females, fewer centers of ossification occur more often on the left than on the right side. These differences are significant on the 5th toes of females ($P < 0.02$), and on the 2nd toes ($P < 0.02$), 3rd toes ($P < 0.05$) and 5th toes ($P < 0.02$) of males and females combined. The differences between feet, when the number of centers of the toes are combined, are also significant in females ($P < 0.02$) and in males and females together ($P < 0.01$).

It may be concluded that when two feet are dissimilar with respect to the types of ossification on the toes there is a tendency for the type with fewer centers to occur more often on the left foot. This result confirms the previous finding that toes as two phalanges occur unilaterally more often on left feet, and toes with three phalanges on right feet, and shows that the same tendency exists among toes with three phalanges with respect to the absence or presence of the epiphysis of the middle phalanx.

6. *Differences between males and females with respect to the types of ossification of the toes.* Males and females have been compared with respect to the frequencies with which ossification types 3 and 4 occur on the 2nd, 3rd and 4th toes, and types 2 and 3 occur on the 5th toe. These frequencies are shown in table 8. It will be observed that in each case the ossification type with fewer centers occurs more frequently in females than in males. Thus, in the 2nd, 3rd and 4th toes type 3 and in 5th toe type 2, is commoner in females than males. The differences are not significant for 5th toes. On the 2nd, 3rd and 4th toes the differences are highly significant for right feet, left feet and bilaterals.

Considered in connection with the previous finding that 5th toes had two phalanges more often in females than males, this result shows that the same difference also exists with respect to the absence of the epiphysis of the middle phalanx on the 2nd, 3rd and 4th toes.

TABLE 8
*Comparisons of males and females with respect to the frequencies with which the
 types of ossification occur on the different toes*

	2ND TOE			3RD TOE			4TH TOE			5TH TOE		
	Type 3	Type 4	P	Type 3	Type 4	P	Type 3	Type 4	P	Type 2	Type 3	P
Right feet:	Males	38	283		131	187		247	68	123	194	Not sig.
	Females	70	267	< 0.01	183	153	< 0.001	288	41	129	201	
Left feet:	Males	44	277		136	181		251	64	126	191	Not sig.
	Females	76	261	< 0.01	191	145	< 0.001	285	43	139	188	
Bilaterals:	Males	35	274		123	174		243	60	114	182	Not sig.
	Females	64	260	< 0.001	176	138	< 0.001	282	38	120	181	

DISCUSSION

If the skeletal types are arranged in an ascending order according to the number of centers of ossification which develop in the phalanx or phalanges distal to the proximal phalanx, the series 1, 2, 3, 4 is obtained. This ascending order of the number of centers corresponds to the latero-medial positional order of the types among the toes when more than one type is present on a single foot. This identity of the numerical order of the number of centers and the positional order among the toes suggests that the skeletal variations may be the expression of some continuous morphogenetic variable with a corresponding latero-medial gradient of values among the toes.

Such a morphogenetic variable, besides the latero-medial gradient across the foot referred to, must be supposed to have markedly different distributions in Japanese and Europeans (see table 1); less pronounced differences in distribution in females and males, and minimal differences in left and right feet. The variable would also be expected to show significantly correlated values in sibs (Venning, '54), in pairs of right and left feet, and in pairs of toes in the same foot.

A variable which appears to satisfy most, if not all, of these requirements is that of digit size — or, more precisely, digit length.

Correlations between the lengths of the segments of particular digit, and the skeletal types will be described in another publication. For the purpose of this discussion it is only necessary to consider the relative lengths of the digits. Pfitzner (1893) found among 301 adult feet only three exceptions to the ascending lengths order of the digits, 5th → 4th → 3th → 2nd. In Pfitzner's material the 1st digit occupied a variable position in this length order, being most commonly longer than the 3rd but shorter than the 2nd digit. Schultz ('24) and Straus ('27) report that in fetuses the 4 lateral digits of the foot are essentially similar in form and undergo comparable changes during fetal growth. Between these 4 digits and the 1st digit considerable relative growth occurs,

the latter becoming relatively longer during development. These investigators measured the distances from the distal ends of the toes to the heels and expressed the descending orders of lengths as 'digital formulae'. Thus between the eighth and twelfth weeks of fetal life the digital formula may be 3, 4, 2, 1, 5 (Schultz) or in one case 3, 4, 2, 5, 1 (Straus). By the eighteenth week the formula becomes either 1, 2, 3, 4, 5, or 1 = 2, 3, 4, 5, or 2, 1, 3, 4, 5. The length of the 1st digit expressed as a percentage of that of the 2nd is reported to increase from about 75% at three months to about 95% at birth. Although the measurements of these investigators do not strictly represent digit length, they show that it is not inconceivable that, at the time of segmentation of the digital skeleton, the 1st digit, which invariably has only two phalanges, may be the shortest digit of the foot, and the 5th digit which frequently has two phalanges, may be the next shortest.

With regard to differences in the digit lengths of females and males, Pfitzner's (1893) measurements clearly show that in adults the mean lengths of all digits are shorter in females. Bakwin and Bakwin ('34) demonstrated similar differences between males and females with respect to foot length at birth. Schultz ('23) on the basis of measurements of a large number of human fetuses concluded that "although clear and unquestionable secondary sexual differences could not be demonstrated in any body proportions, the general size is slightly greater in males during the last two months of fetal life."

Hasebe ('12b) gives measurements of the mean lengths of the metatarsals and proximal phalanges of the digits of a sample of Japanese adults. If these measurements are compared with the corresponding measurements of European adults given by Pfitzner (1893), it is seen that in the case of each digit the mean lengths of the Japanese sample are shorter even than those of the females of Pfitzner's material. Measurements at birth seem to show that the body dimensions of Japanese born in America are greater than those of native born Japanese, and in the case of foot length no smaller than in Europeans (Ito, '36). If this is so, it would be interesting

to know whether the frequencies of 5th toes with two phalanges show corresponding differences between native born and American born Japanese.

High correlations with respect to digit lengths between right and left feet, and between pairs of digits of the same foot certainly occur, and will be reported in another communication. With regard to length correlations between sibs, Pearson and Lee ('03) found, with respect to stature and length of forearm, correlations, irrespective of sex, of 0.534 and 0.479 respectively.

In this connection the observations of Bakwin and Bakwin ('34) are of interest. These authors showed that body dimensions, including foot length, are correlated with birth order; the mean lengths being less in both sexes in the first-born. Venning ('54) however, did not find any birth order effect with respect to the frequencies of occurrence of two phalanges in the 5th toe.

No report has been found of differences between right and left feet with respect to digit lengths in either fetuses or newborn. Pfitzner's (1893) measurements on adults do not appear to show any systematic or significant differences between the two sides.

It may be concluded that there is an association between digit length and the different skeletal types, such that the skeletal forms with the smaller number of centers of ossification and phalanges are correlated with short digits. Such a correlation does not in itself indicate either that there is a causal connection between the two nor, if such a connection is presumed, which is the consequence of the other. Indeed it is possible that the absence of epiphyses or phalanges might itself result in some shortening of the digit. It can easily be shown however that such shortening does not account either for the medio-lateral length gradient of the digits or the length differences found in males and females and Europeans and Japanese. These differences exist independently of skeletal type and are found among those digit segments not directly involved in the skeletal variations. The correlation

between skeletal type and digit lengths may not therefore be accounted for by supposing the latter to be a consequence of the former. The reverse hypothesis that digit length differences, already established in the embryonic blastemata prior to the segmentation of the phalanges, give rise to the different skeletal types remains a possibility consistent with the evidence so far considered. This hypothesis assumes that the continuous distribution of some morphogenetic variable, with which digit length is correlated, is divided into 4 ranges by three critical threshold values; each range corresponding to one of the skeletal types.

Further evidence relevant to this hypothesis will be discussed in another communication.

SUMMARY

1. The radiographic appearances of different types of ossification of 2nd-5th toes are described. Four types are distinguished according to the number of centers of ossification that develop distal to the proximal phalanx.

2. The terminal phalanx of toes with two phalanges may ossify from either one or two centers. The middle phalanx of toes with three phalanges may ossify either from a single center or a primary center and an epiphysis.

3. The radiographs of samples of children and adults are analyzed by sex, age, and right and left feet with respect to these types of ossification on the different toes.

4. When more than one type of ossification occurs on the same foot, toes with the larger number of centers are medial to toes with a smaller number. Consequently toes with three phalanges are medial to those with two.

5. The presence of two phalanges on the 5th toe is significantly associated with the absence of an epiphysis of the middle phalanx of the other toes.

6. There is a highly significant tendency for pairs of right and left feet to be the same with respect to the types of ossification on the different toes.

7. Unilateral occurrences of types of ossification with a reduced number of centers of ossification and phalanges are significantly more common on left feet than on right feet.

8. Toes with a reduced number of centers of ossification and phalanges occur significantly more often in females than in males.

9. No age differences in the frequencies of occurrence of toes with two or three phalanges were found.

10. The frequency distributions of the different skeletal forms found in this and other studies show that those forms of ossification with the fewer centers (and phalanges) are correlated with short digits. This correlation exists independently of the length differences produced by the varying number of centers and phalanges present. The hypothesis is suggested that digit length is the morphogenetic variable causing the skeletal differences.

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CHANGES IN LUMBAR VERTEBRAL BODY HEIGHT WITH AGE

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Recent work has established on a quantitative basis the decremental age changes found in human skeletal material, mainly using the long bones of the body (Trotter, '52).

It is therefore of interest to report on the somewhat unexpected findings resulting from an analysis of vertebral skeletal material from East Africa.

MATERIAL

Seventy-two vertebral columns were studied, of which 21 were female. Only columns having 5 lumbar vertebrae which were free from osteophyte formation or other pathological change were used. The age distribution of the skeletons was within the range of 20 to 45 years (table 1). The main tribal groupings are similar to those reported previously (Allbrook, '55).

METHOD

Simple caliper measurement of the median anterior and posterior vertebral body height was performed on each lumbar vertebra. The result was recorded in millimetres and the posterior minus the anterior height (subsequently termed the [P-A] value) was assessed as a positive or negative value. A positive (P-A) value indicates a longer posterior body height than the anterior height, or, in terms of the whole region, a kyphotic curve. A negative (P-A) value indicates a greater anterior vertebral body height, or a lordotic curve in the region as a whole. The point of contraflexure can therefore be assessed at the point where the (P-A) value changes from a positive to a negative value.

The data was analysed statistically for the possible influence of such factors as sex, age and tribe on the average body height (both anterior and posterior) and on the point of contraflexure.

RESULTS

The average combined total height of the 5 lumbar vertebrae is given in table 2. The result shows that the male columns are significantly longer than the female columns.

TABLE 1
Age distribution of skeletal material analysed

	20—	25—	35—	45—50	UNKNOWN	TOTAL
Male	8	14	14	7	8	51
Female	2	6	8	3	2	21

TABLE 2
The average combined total height of L 1-L 5

	ANTERIOR	S.D.	POSTERIOR	S.D.
Male	130.5	8.7	132.6	8.7
Female	128.2	2.0	128.6	1.8

TABLE 3
Average total height of each individual vertebra
(51 male, 21 female)

SEGMENT	SEX	POSTERIOR HEIGHT (P)	S.D.	ANTERIOR HEIGHT (A)	S.D.	(P-A)
L 1	Male	27.37	1.70	25.19	1.76	+ 2.17
	Female	26.50	0.28	25.00	1.22	+ 1.50
L 2	Male	27.85	1.88	26.02	1.87	+ 1.82
	Female	27.10	1.45	25.81	1.42	+ 1.29
L 3	Male	27.64	2.00	26.30	1.94	+ 1.35
	Female	26.60	1.52	26.10	1.34	+ 0.50
L 4	Male	25.92	2.10	26.20	2.56	— 0.27
	Female	25.10	1.77	25.50	1.42	— 0.40
L 5	Male	23.90	2.18	26.78	2.72	— 2.88
	Female	23.40	1.42	25.80	1.58	— 2.40

The average height of individual lumbar vertebrae, of each sex, is compared in table 3. This indicates that the increased height in the skeletons is found in all vertebrae, in both anterior and posterior dimensions. The point of contraflexure lies between L 3 and L 4 in both male and female series.

The influence of age was tested by separating the material into 5 year groups ranging from 20 to 45 years. As the influence of sex was so marked the test was performed separately for male and female series. A scatter diagram was constructed to show the effect of age on the total height of the 5 lumbar vertebrae. In the male series the effect of age can be demonstrated by fitting a straight line to the data, and testing for the significance of the reduction of variance. This is significant (P . less than 0.1) and the estimated values in the age groups analysed are as follows:

YEARS	15--	25--	35--	45--
Total lumbar posterior height	129.9	132.4	134.9	137.4

The mean value at 35 (exact age) being 133.67 with an annual increment of $+0.24$.

Similarly with the anterior height, the mean at 35 (exact age) was 131.0, with an annual increment of $+0.20$.

In the female series the mean value at 35 (exact age) was 129.4 posterior height with an annual decrement of -0.13 , which is not a significant value.

A more detailed study of individual vertebrae in the male series was undertaken. A decisive increase in both anterior and posterior height of each vertebra with increasing age was demonstrated. No such significant trend could be found in the female series.

For the purposes of analysis the material was separated into 5 main tribal groupings, namely Rwanda, Rundi, Nilotics, Ganda and the heterogenous residue "others." No significant differences in total height of the lumbar vertebrae was found between these groups, that could be attributed to tribal factors.

DISCUSSION

The greater height of lumbar vertebral bodies in male skeletons as compared with female is not surprising and confirms the findings of Trotter ('29). In this series the apparent length is considerably greater than the figures given by this author although they are comparable with the values recorded by Todd and Pile ('28).

The point of contraflexure is low, being between L 3 and L 4, a feature which has been found in protohistoric African material (Galloway, unpublished data), and contrasts with the high point of contraflexure (between L 2 and L 3) in American white and negro material (Trotter, '29). The level of contraflexure therefore appears as a racial character not influenced by sex, or in this series by age. (It is however influenced by the number of vertebral segments. For in 12 out of 14 columns having 25 segments the point of contraflexure lay between L 4 [23] and L 5 [24].)

The increase in height of each lumbar vertebra within the age range 20-45 years in males, is of great interest. It is unexpected, for one imagines that once maturity is reached no further change in vertebral height could occur other than that of senile osteoporosis. On the other hand, smooth bony accretion to the epiphysial ring could be the cause of this increase in height, for both anterior and posterior heights are affected. In a study of the stature of English girls between the ages of 18 and 21, Matthew Young ('28) found a small increase in the stem height. He accounted for this by postulating an increase in vertebral epiphysial plate thickness, but admitted the possibility of uncontrolled factors influencing the results. Perhaps it is not out of place to quote relevant hearsay evidence. A number of educated African men have mentioned to the author that they think they continue to grow in stature whilst at College and during their internship in hospital. No direct evidence is available at the moment although longitudinal growth studies are in progress both at Makerere College and in the M.R.C. Infantile Malnutrition Unit at Mulago Hospital.

The increase in height of lumbar vertebrae with age was found in male skeletons only. In the female series there was no definite change in height, although there was a suggestion of actual decrease in height which was not statistically significant in the small sample examined. Nevertheless, this difference between the sexes may be of importance and it is tempting to speculate that perhaps the metabolic demands made on the female by frequent pregnancies and lactation in the age range between 20 and 45 years may be a possible cause.

SUMMARY

1. In a series of East African skeletons the anterior and posterior height of lumbar vertebrae was measured.
2. The combined lumbar vertebral body height was longer in males than in females.
3. The point of contraflexure lay between L 3 and L 4, and was uninfluenced by age, sex, or tribe, but was influenced by the number of prevertebral segments.
4. In male skeletons there was a significant increase in both anterior and posterior vertebral body height in the age range 20-45 years. This was not apparent in female skeletons.

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A CHROMATOGRAPHIC INVESTIGATION OF URINARY AMINO-ACIDS IN THE GREAT APES

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SIX FIGURES

INTRODUCTION

Compared to the numerous and detailed investigations of the anatomy, particularly the skeletal anatomy, of the great apes, very little is known about the physiological and biochemical characteristics of this group of primates. This is, of course, understandable because of the relative inaccessibility of living apes for physiological study. And yet, comparative physiology and biochemistry may yield information which could be no less enlightening than comparative anatomy for the study of the evolutionary relationships of the higher primates, including man. That information of this sort may actually be forthcoming from physiological studies is strongly suggested by the most interesting results of the investigations such as that of Wells and Caldwell ('14) on purine metabolism, of Bruhn ('34) on respiratory metabolism, and of Smith and Clarke ('38) on creatinine clearance.

The rapid development of analytical techniques by means of partition chromatography on paper has furnished an opportunity to obtain at least rough preliminary data concerning an important aspect of the metabolic processes in several species of apes, namely, the excretion in urine of certain amino-acids. A considerable amount of work of this kind on human subjects has been done in recent years (see Berry, '53;

and Berry, Dobzhansky, Gartler, Levene and Osborne, '55, for further references). For comparison with these human data, we have endeavored to obtain determinations of the free amino acids excreted in the urine of 4 species of apes — chimpanzee, gorilla, orang-utan, and gibbon. Unfortunately, the numbers of individuals of these different species which we were able to examine proved very unequal, the chimpanzee being more numerous than the other three combined. Even so, the data show quite clearly that the urinary amino acids in the apes are quantitatively, and in part even qualitatively, very different from what they are in man. Some differences between the apes themselves are also indicated, although because of the great individual variability observed the inter-specific differences cannot be regarded established as firmly as can be desired.

MATERIAL AND METHODS

As shown in table 1, we obtained urine samples from 37 chimpanzees, 6 gorillas, 3 orangs and 2 gibbons (*Hylobates lar*). These animals have been living in several different zoological gardens and presumably received somewhat different diets and treatments. However, the relatively large series of chimpanzees from Yerkes Laboratory, at Orange Park, Florida, live under relatively standardized conditions. The ages of the animals are, when known, indicated in table 1. It can be seen that they varied from babies to individuals approaching senility.

The collection of urine samples from apes presents obvious difficulties. Only in two cases has it been possible to obtain sterile samples by catheterization of living animals; these were obtained from the two chimpanzees at the College of Physicians and Surgeons, Columbia University (table 1). In 7 other instances, the animals, chiefly young ones, were placed in metabolic cages for the purpose of obtaining urine samples. In all other cases (table 1) the urine was siphoned off from a special cage floor which was washed and dried between collections, or even siphoned off from the unwashed cage

TABLE 1

Name, species, age, location and methods of urine collection for animal studies

Methods of collection; 1. Catheterized; 2. Metabolic cage; 3. Washed cage floor; 4. Unwashed cage

NAME	SEX	AGE years	LOCATION	COLLECTION METHODS	SPECIES	NAME	SEX	AGE years	LOCATION	COLLECTION METHODS
3-1	♀	A ¹	Columbia Univ.	1	CHIMPANZEES	Norma	♀	2	Yerkes Lab.	2
3-2	♀	A ¹	Columbia Univ.	1		Pati	♀	35	Yerkes Lab.	3
2-4	♂	I ¹	University of Virginia	2		Pandit	♂	1	Yerkes Lab.	2
	♂	16	Yerkes Lab.	3		Pitipie	♀	12	Yerkes Lab.	4
	♀	19	Yerkes Lab.	3		Sheba	♀	4	Lincoln Park Zoo, Chicago	4
	♂	16	Yerkes Lab.	3		Snark	♂	10	Yerkes Lab.	3
	♀	14	Yerkes Lab.	3		Susie	♀	A ¹	Lincoln Park Zoo, Chicago	4
	♂	15	Yerkes Lab.	3		Vera	♀	23	Yerkes Lab.	3
	♂	30	Yerkes Lab.	3		Web	♂	12	Yerkes Lab.	4
	♀	25	Yerkes Lab.	3		Wendy	♀	1	Yerkes Lab.	2
	♀	18	Yerkes Lab.	3		Went	♂	1	Yerkes Lab.	2
	♂	21	Yerkes Lab.	3	GORILLAS	4-2 Toto	♀	23	Ringling Bros. Circus	4
	♀	12	Yerkes Lab.	4		4-1	♂	5	Ringling Bros. Circus	4
	♀	13	Yerkes Lab.	4		Joan	♀	A ¹	Central Park Zoo, Chicago	3
	♀	14	Yerkes Lab.	3		Young	♂	9	Lincoln Park Zoo, Chicago	4
	♂	11	Yerkes Lab.	3		Rajah	♂	8	Lincoln Park Zoo, Chicago	4
	♀	2	Yerkes Lab.	2	ORANGS	Sinbad	♂	8	Lincoln Park Zoo, Chicago	4
nie I	♂	34	Lincoln Park Zoo, Chicago	4		6-1	♀	3	Central Park Zoo, N. Y.	4
nie II	♂	7	Lincoln Park Zoo, Chicago	4		6-2	♂	2	Central Park Zoo, N. Y.	4
	♀	15	Yerkes Lab.	3	GIBBONS	Ling Wong	♂	14	Lincoln Park Zoo, Chicago	4
	♂	13	Yerkes Lab.	3		7-1	♀	15	N. Y. Zool. Park	4
	♂	15	Yerkes Lab.	3		7-2	♂	15	N. Y. Zool. Park	4
	♀	6	Yerkes Lab.	4						
	♂	16	Yerkes Lab.	3						
colm	♂	2	Yerkes Lab.	2						

et age unknown; A = adult; I = immature.

floors. In the last named situation care was, of course, taken not to collect urine samples if there were obvious signs of contamination on the floor. A few thymol crystals were added to each sample as a preservative, and the samples were deep frozen as soon as possible after collection.

The reliability of the urine samples obtained by the last methods may seem questionable. The best evidence that no contamination serious enough to vitiate the data occurred, can be seen in the consistency of the data themselves. Only two animals were catheterized to obtain samples, but these samples can serve as contamination controls for the others. Although these two animals were living in a place different from all others, and might have been treated differently, their urines were not appreciably different from the others. Samples obtained in the metabolic cage also compare reasonably well with those obtained from cage floors. The group of chimpanzees at the Yerkes Laboratory is especially significant, since there the samples were collected by three different methods (all except catheterization) from animals which were otherwise treated fairly uniformly; no consistent differences between the samples obtained by the three methods have appeared.

The techniques of paper chromatography used in this study have been described elsewhere (Berry, '53; Berry, Dobzhansky, Gartler, Levene and Osborne, '55) and need not be repeated in detail here. Most amino acids were studied by two-dimensional ascending chromatography, using phenol and lutidine as solvents and a 0.2% solution of ninhydrin in butanol as a developer. Histidine determinations, however, were made on unidimensional chromatograms prepared according to the method of Cain and Berry ('51). The spots resolved by these paper chromatographic techniques were identified by their migration characteristics and their color reactions with various reagents. Quantification was carried out by measuring the optical density of the colored spots, the optical density generally being proportional to the amount of material present in the spot. A Photovolt densitometer was used for

optical density determinations. Creatinine determinations were made colorimetrically according to Bonsnes and Taussky ('45).

Creatinine concentration

Ideally, one would like to study the total amounts of various amino acids and other substances excreted by individual animals during whole days or longer intervals. In practice, complete daily samples are difficult to obtain in human subjects (except in hospitalized patients), not to speak of apes. For this reason, in the work with paper chromatography of urine one has to be satisfied with only partial samples. This raises the difficulty that the water contents of urine vary

TABLE 2
Creatinine concentrations in apes and man

SPECIES	MEAN MG CREATININE PER ML OF URINE	STANDARD DEVIATION
Chimpanzee	0.48	0.43
Gorilla	0.21	0.20
Orang-utan	0.34	0.19
Gibbon	0.41	0.04
Man	1.47	0.68

greatly, and the concentration of various substances calculated per volume units are equally variable. Accordingly, it is considered more meaningful to express the concentrations of the amino acids per units of creatinine excreted in the urine. This substance is known, in man, to be excreted at daily rates which are less variable than the excretion rates of other substances, since the creatinine excretion is strongly correlated with the muscle mass in the individual. In tables 3 and 4 the concentrations of aspartic and glutamic acids, and of glycine, taurine, alanine, threonine, lysine, valine, tyrosine, and histidine, are expressed in milligrams of respective substances per milligram of creatinine excreted.

For purposes of comparisons of the excretion patterns in apes with those in man, it is most important to take into

account that the creatinine concentrations per unit volume of urine are much higher in man than in apes, as shown in table 2.

Although the creatinine concentrations are variable in all species, it is clear that human urine contains on the average three times as much creatinine per unit as that of chimpanzee. The creatinine concentration in the gorilla seems to be significantly lower than in the chimpanzee.

This is of considerable interest from a comparative standpoint, and is probably of some importance physiologically, as we shall indicate. However, it presents a problem in the comparing of amino acids excretion rates between species. This is so because in spite of its variation from one species to another, creatinine concentration is used as a reference substance. Clearly, under such conditions an apparent difference in amino acid excretion rates between species may not represent differences in excretion rates at all, but may merely reflect differences in creatinine concentration. For most amino acids measured, the apparent excretion rates were higher for apes than for man. In order for such differences in apparent amino acids excretion rates to represent real ones, the magnitude of differences must be at least greater than the creatinine concentrations differences between the groups being compared. In one instance, that of histidine, the apparent amino acid excretion rate is higher for man than for apes; in such a case a real difference in excretion rates is even greater than the apparent one, since the creatinine concentration differences will tend to mask the amino acid ones.

The physiological meaning of this very striking difference in creatinine concentration between man and apes is not clear from our data. It seems most likely that a major factor is a difference in the volume of urine passed per unit of body weight in a given time. If creatinine excretion is a measure of the muscle mass, the amounts excreted by a gorilla must be at least equal, and probably greater, than in man. On this assumption, a gorilla must produce an average daily volume of urine about 7 times greater than man, this being

NAME	ASPARTIC	GLU- TAMIC	GLY- CINE	TAURINE	ALA- NINE	THREO- NINE	GLUTA- MINE	LYSINE	VALINE	LEU- CINE	BETA- ALANINE	TYROSINE	HISTIDINE	IT	PROLINE	X	CREA- TININE
3-1	<0.001	0.008	0.092	0.260	0.015	<0.012	0.75	<0.005	0.020	0.00	0.67	<0.025	<0.010	1.00	-	0.00	1.32
3-2	0.005	0.018	0.043	<0.012	0.012	<0.012	0.00	<0.005	<0.010	0.00	0.50	<0.025	<0.010	0.00	-	0.00	0.44
3-4	0.002	0.056	0.028	<0.012	0.010	0.055	1.00	0.021	0.060	0.00	0.00	<0.025	<0.010	0.00	-	0.00	0.22
Alf	0.003	0.055	0.068	0.165	0.042	0.116	2.05	<0.005	0.028	0.00	0.62	0.030	0.110	0.00	-	0.24	0.68
Ami	0.020	0.135	0.140	0.350	0.080	0.170	2.34	<0.010	0.070	0.00	0.40	<0.100	<0.010	0.13	-	0.20	2.20
Art	0.005	0.052	0.055	0.060	0.047	0.112	1.18	<0.010	<0.025	0.00	0.47	<0.050	<0.010	0.00	-	0.00	0.24
Banka	0.002	0.077	0.067	0.060	0.050	0.290	1.80	0.016	0.020	0.09	3.14	0.050	0.040	0.09	+	0.09	0.54
Bard	0.002	0.026	0.034	0.080	0.030	0.017	0.50	0.006	0.010	0.11	0.24	<0.025	<0.010	0.00	-	0.00	0.42
Bokar	0.060	0.440	0.375	0.135	0.275	0.017	0.73	0.085	0.080	0.03	0.20	<0.100	0.00	0.00	+	0.32	0.04
Bula	0.050	0.300	0.220	0.400	0.150	0.660	1.32	0.030	<0.050	0.36	0.28	<0.250	0.00	0.12	+	0.10	0.10
Coma	0.007	0.025	0.070	0.090	0.028	0.030	0.64	0.010	0.025	0.00	0.36	<0.050	0.020	0.00	-	0.00	0.22
Don	0.004	0.036	0.011	0.100	0.040	0.094	1.85	0.005	0.014	0.00	0.56	<0.025	<0.010	0.22	-	0.00	0.98
Dolly	0.000	0.043	0.125	0.100	0.027	0.015	0.67	0.005	0.010	0.00	0.00	<0.025	<0.010	0.00	-	0.00	1.08
Falla	0.024	0.100	0.125	0.032	0.075	0.238	1.24	0.030	<0.020	0.13	0.27	<0.025	0.080	0.11	+	0.11	0.33
Fanny	0.011	0.120	0.160	0.165	0.080	0.265	1.42	0.005	0.050	0.00	0.50	<0.100	0.00	0.00	-	0.00	0.07
Flora	0.039	0.110	0.190	0.060	0.050	0.620	4.20	0.032	0.115	0.40	0.70	0.185	0.360	0.00	+	0.30	0.36
Frans	0.020	0.100	0.110	0.055	0.080	0.085	1.08	<0.010	0.030	0.19	0.23	<0.050	<0.010	0.31	+	0.00	0.22
Garbo	<0.020	0.350	0.040	0.00	0.220	0.250	0.92	<0.010	0.050	0.00	0.20	0.190	0.110	0.54	-	0.00	0.44
Hienie I	0.009	0.100	0.105	0.00	0.030	0.035	0.00	<0.005	0.030	0.29	0.29	<0.025	<0.010	0.33	-	0.00	0.72
Hienie II	0.004	0.300	0.400	<0.050	0.120	0.087	0.00	<0.010	0.063	0.33	0.06	<0.050	<0.010	0.35	-	0.00	0.40
Jenny	0.004	0.011	0.043	0.060	0.022	0.035	1.06	0.045	<0.010	0.00	0.00	<0.025	<0.010	0.18	-	0.00	0.68
Jent	0.008	0.060	0.110	0.200	0.041	0.090	1.60	0.012	0.025	0.00	0.75	<0.050	<0.010	0.00	-	0.00	0.32
Jojo	0.015	0.070	0.079	0.00	0.040	0.058	0.57	0.049	<0.010	0.00	0.38	<0.025	<0.010	0.00	-	0.15	0.18
Kathy	0.010	0.050	0.090	0.00	0.020	0.068	0.73	<0.005	0.010	0.00	0.00	<0.025	<0.010	0.00	-	0.00	0.18
Ken	0.030	0.080	0.105	0.00	0.090	0.015	0.24	0.027	<0.010	0.06	0.22	<0.025	<0.010	1.00	-	0.00	0.17
Malcolm	0.020	0.110	0.035	0.280	0.065	0.275	0.54	0.038	0.050	0.17	0.30	<0.250	<0.110	0.32	-	0.00	0.17
Norma	0.011	0.110	0.093	0.350	0.060	0.280	1.50	0.027	0.020	0.00	1.00	<0.025	0.130	0.00	-	1.00	0.40
Pati	0.040	0.120	0.185	<0.030	0.077	0.120	1.35	<0.020	<0.050	0.00	0.27	<0.100	<0.010	0.00	-	0.79	0.70
Pandit	0.013	0.123	0.040	0.025	0.038	0.290	1.74	<0.010	0.020	0.00	0.78	<0.050	<0.010	0.00	-	0.45	0.21
Pipie	0.011	0.100	0.180	0.085	0.031	0.015	0.70	0.080	0.020	0.00	0.17	<0.025	<0.010	0.00	-	1.00	0.43
Sheba	0.010	0.100	0.400	<0.050	0.100	<0.050	0.00	<0.010	0.030	0.00	0.00	<0.100	<0.010	0.00	-	0.00	0.58
Snark	0.014	0.155	0.230	0.350	0.067	0.088	0.77	<0.050	0.025	0.00	0.46	<0.050	<0.010	0.50	-	0.00	0.29
Susie	0.068	0.370	0.220	<0.050	0.220	0.132	0.05	<0.010	0.060	0.26	0.14	<0.050	<0.010	0.00	-	0.29	0.30
Vera	<0.001	0.019	0.020	0.062	0.007	0.079	5.28	<0.005	0.015	0.00	1.43	<0.025	<0.010	0.53	-	0.00	0.29
Web	0.010	0.135	0.135	0.00	0.040	0.220	2.18	0.035	<0.025	0.00	1.34	<0.050	<0.010	1.00	-	1.00	1.40
Wendy	0.018	0.100	0.110	0.00	0.100	0.530	1.88	0.037	<0.025	0.05	0.00	<0.075	<0.010	0.00	-	0.00	0.24
Went	0.010	0.116	0.045	0.00	0.040	0.124	1.72	<0.010	<0.025	0.00	1.28	<0.050	<0.010	0.00	-	0.00	0.25
4-1	0.055	0.395	0.262	0.425	0.250	<0.050	0.16	<0.020	<0.050	0.00	0.14	<0.100	<0.010	0.10	-	0.00	0.34
4-2	0.155	1.025	0.300	1.200	0.400	<0.050	0.37	<0.020	<0.050	0.00	0.18	<0.100	<0.010	0.40	+	0.00	0.43
Joan	0.020	0.085	0.090	0.150	0.065	0.330	2.62	0.135	<0.050	0.00	0.54	<0.100	0.00	0.00	-	0.00	0.08
Young	0.060	0.310	0.600	0.260	0.420	0.440	0.26	<0.030	0.260	0.50	0.53	<0.100	<0.010	0.00	-	1.50	0.48
Rajah	0.320	0.850	1.000	0.275	0.950	<0.100	0.16	<0.020	0.450	0.43	0.05	<0.100	0.022	0.00	-	0.54	0.02
Simbad	0.185	0.400	0.400	<0.000	0.220	<0.050	0.00	0.050	0.200	0.10	0.10	<0.100	0.020	0.00	-	0.17	0.04
6-1	0.022	0.125	0.180	0.155	0.170	<0.025	0.08	<0.015	0.030	0.00	0.00	<0.050	<0.010	0.13	+	0.13	0.70
6-2	0.080	0.215	0.205	0.340	0.205	0.210	0.62	<0.015	0.065	0.00	0.00	<0.050	<0.010	0.00	+	0.00	0.22
Ling Wong	0.040	0.400	0.350	0.00	0.155	0.190	0.00	<0.030	0.135	0.50	0.00	<0.050	0.030	0.90	-	0.00	0.09
7-1	0.005	0.035	0.090	0.105	0.015	<0.012	1.18	0.020	<0.012	0.00	0.00	<0.025	<0.010	1.00	-	0.00	0.70
7-2	0.030	0.075	0.085	1.000	0.140	<0.050	0.66	0.125	<0.012	0.00	0.00	<0.025	<0.010	0.54	-	0.00	0.12

the ratio of the average creatinine contents in the gorilla and human urines. The same applies, though to a lesser degree, to the other apes.

Amino acids

The concentrations of the different substances in the urine samples of individual animals are shown in table 3, while table 4 gives the means and their standard errors. As stated above, the concentrations of most substances are expressed in these tables in terms of milligrams per milligram of the creatinine excreted. For some substances this could not, however, be done since we did not have control chromatograms that would permit the conversion of the optical densities of the spots observed into weight units. For these substances, glutamine, leucine and β -alanine, and the unknown substances designated as LT and X, the data are shown in terms of ratios of the optical density of the spots observed with that of the alanine spot on the same chromatograms. The average values for human subjects reported in table 4 are computed from the data of Berry ('53); Berry, Dobzhansky, Gartler, Levene, and Osborne ('55); and Gartler, Dobzhansky, and Berry ('55).

Several quite striking and significant differences between the urinary excretion patterns in man and in the apes are apparent at once. They can be listed as follows, more or less in the descending order of the magnitude of the difference. Man excretes much more histidine than the apes do. In man, the amounts of histidine excreted are as great as, or greater than those of any other amino acid. Among the apes, histidine is excreted in amounts smaller than several other amino acids. In this respect, chimpanzee seems closest to man, while the two gibbons which we studied had only traces of histidine in their urines.

Conversely, apes excrete much more glutamic and aspartic acids than humans do. The differences in the excretion rates of these substances are significant between man and chimpanzee, man and gorilla, and even man and orang, although

TABLE 4

Means and standard errors of amino acids reported as milligrams amino acid/mg creatinine and those reported as ratio of optical density of amino acid/optical density alanine

AMINO ACID	MG AMINO ACID/MG CREATININE			
	Chimpanzees	Gorillas	Orang-utans	Gibbons
Aspartic	0.017 ± 0.009	0.132 ± 0.046	0.047 ± 0.036	0.019 ± 0.012
Glutamic	0.115 ± 0.017	0.511 ± 0.144	0.247 ± 0.080	0.058 ± 0.021
Glycine	0.122 ± 0.016	0.442 ± 0.131	0.245 ± 0.053	0.093 ± 0.002
Taurine	0.138 ± 0.018	0.420 ± 0.244	0.248 ± 0.092	0.587 ± 0.447
Alanine	0.071 ± 0.010	0.384 ± 0.125	0.117 ± 0.047	0.083 ± 0.078
Threonine	0.167 ± 0.026	0.170 ± 0.070	0.142 ± 0.059	0.033 ± 0.019
Lysine	0.022 ± 0.003	0.080 ± 0.033	< 0.020	0.076 ± 0.053
Valine	0.031 ± 0.005	0.177 ± 0.067	0.077 ± 0.031	< 0.012
Tyrosine	0.078 ± 0.010	< 0.100	< 0.050	< 0.027
Histidine	0.052 ± 0.011	0.014 ± 0.003	0.017 ± 0.007	< 0.010
OPTICAL DENSITY OF AMINO ACID/OPTICAL DENSITY ALANINE				
Glutamine	1.27 ± 0.22	0.58 ± 0.45	0.23 ± 0.06	0.92 ± 0.26
Leucine	0.07 ± 0.02	0.21 ± 0.10	0.17 ± 0.17	0.00
β-Alanine	0.53 ± 0.09	0.26 ± 0.09	0.00	0.00
LT	0.19 ± 0.05	0.08 ± 0.06	0.34 ± 0.28	0.77 ± 0.23
X	0.17 ± 0.05	0.06 ± 0.08	0.04 ± 0.05	0.00
				0.81 ± 0.009
			
				~ 0.00
				~ 0.00
				~ 0.00

only three individuals of the last named species have been sampled. The two gibbons also showed more glutamic acid than is usual in human urines; one of the specimens had, however, only a small, though measurable, amount of aspartic acid in its urine. The glutamic acid spot is one of the most conspicuous spots on chromatograms of ape urines (figs. 1-6), while it is often invisible in chromatograms of human urines.

Beta-alanine occurs rarely in human urines (we have seen the β -alanine spot in about 1% of the human samples which we have examined). It is quite common in chimpanzee and in gorilla, although some specimens have this spot only weakly pronounced or even invisible. The orang and gibbon samples seemed to be free of this substance. Proline is another amino acid which rarely appears in human urines in concentrations sufficient to give a discernible yellow spot on ninhydrin-developed chromatograms. This spot was, however, quite clear on some chimpanzee, gorilla, and orang chromatograms.

The chimpanzee samples have shown a significantly higher mean concentration of threonine than did human samples. Threonine appears to be high also in gorilla and orang samples, though the difference from man is no longer significant statistically. The value for the gibbon is ostensibly like that in man. The substances referred to in tables 3 and 4 as LT and X are unknown. They appear, on phenol-lutidine chromatograms, in positions close to that in which the β -aminoisobutyric acid spot appears in the chromatograms of human urine. It may be that the LT spot in at least some of the ape urines actually represents the β -aminoisobutyric acid, although this is not quite certain. The spot X, which lies slightly to the left of LT is rare or absent in human samples.

It may be noted that the differences enumerated above differentiate, for the most part, between human and ape urines as groups. There doubtless exist also differences between the different species of apes, but they are less pronounced than those between man and apes. As pointed out above, the excretion rates of histidine are probably higher

in chimpanzee than in other apes, while gorillas seem to stand out because of the high excretion rates of aspartic and glutamic acids, glycine and alanine. More observations are, however, needed to establish this, particularly on gorillas, oranges, and gibbons.

Dietary effects

The question which occurs at once is to what extent the observed differences between man and apes in the excretion rates may be due to the dietary differences between them. To be sure, it is most unlikely that any dietary factor or factors could be responsible for the low histidine excretion and the high glutamic, aspartic, and threonine excretion rates observed in the apes compared to man. Nevertheless, we felt it necessary to check on this point by some experiments. Three of the members of our Laboratory agreed to keep themselves for 2, 4, and 6 days respectively on a diet approaching that given the chimpanzees at the Yerkes Primate Laboratory at Orange Park, Florida. The main constituents of this diet are "chimp crackers," soy-bean "cake," fruit and water. The urinary excretion patterns of these three persons were examined before, during, and after the days of the experimental diets. In no case were significant changes observed, particularly no changes in the direction of the excretion patterns in the apes.

Another dietary study which bears, though indirectly, on our problem is that of Rheinberger ('36) on nitrogen partition in apes. This author kept two human subjects on a diet similar to that of apes, for some days, and found that the major differences in nitrogen partition between man and the apes studied remained unaffected. We are inclined to believe that appreciable differences in the intermediary metabolic patterns, or differences in the renal functions with respect to several amino acids studied, exist between man and the apes. More rigorous experimental techniques will, however, be necessary to throw light on the physiological nature of these differences.

Variability of the excretion rates within a species

Examination of table 3 shows that the excretion rates of various substances vary greatly not only between species but also between individuals of the same species. The standard deviations for the excretion rates computed from our data are often as large as the mean rates for the respective substances; in other words, the coefficients of variation observed between samples from the same species are of the order of 100. The chimpanzee data appear to give the highest variation coefficients. The great variability can be seen also in figures 3 and 4, which are photographic reproductions of two chromatograms of gorilla urine. The differences between these chromatograms are quite pronounced.

DISCUSSION

The urinary excretion patterns observed in the anthropoid apes are strikingly different from those in human subjects. At any rate, the man-ape differences are much greater than those between the different species of the anthropoids themselves. Man excretes much more histidine than the apes do, while ape urines show high concentrations of glutamic and aspartic acids, and a frequent presence of β -alanine. These facts are suggestive of quite fundamental differences between the intermediary metabolic mechanisms in man and the apes, but taken by themselves they do not permit a definitive evaluation of the nature of the differences observed. Such an evaluation would require a thorough investigation of the metabolism, and particularly of the renal clearances, in the apes.

In this connection, the remarkable physiological difference between the Dalmatian and other dog breeds may well be cited for comparison (Trimble and Keeler, '38; Friedman and Byers, '48; and others). Dalmatian dogs excrete much more uric acid than allantoin in their urine, while other dog breeds and other carnivores excrete chiefly allantoin. It happens that man and chimpanzee also excrete uric acid, while mon-

keys, as far as known, excrete chiefly allantoin. The difference between the Dalmatian and other dogs is due to a single gene, of which the Dalmatian breed carries the recessive allele. Now, uric acid can be transformed into allantoin with the aid of an enzyme, uricase, and a suggestion has been made that the Dalmatian dogs may lack this enzyme. In reality, the uricase activity proved to be about equal in the livers of the Dalmatian and of other breeds, and it has been shown that the differences between these breeds depend chiefly on the renal clearance mechanisms. Both uric acid and allantoin are present in the blood plasma of all dogs, and both are excreted by the kidney glomeruli. But while in most dogs the uric acid is reabsorbed in the kidney tubules, it is largely passed into the urine in the Dalmatians. Thus, the scarcity of, say, histidine in ape urine does not necessarily prove that histidine is scarce also in the blood of these animals.

In two respects, the amino acid contents of the ape urines resemble those of human infants, rather than of adult men. These are the high concentrations of the glutamic and aspartic acids. As shown by Berry ('54), and confirmed by some of our own data on human subjects (unpublished), glutamic and aspartic acids appear in quantities detectable in the chromatograms rather frequently in infant urine but only rarely in adults (especially the aspartic acid). The low creatinine contents of the ape urines again resemble these in human infants (which approach those recorded by us in the chimpanzees). This might suggest that, with respect to the urinary excretion patterns, adult men are gerontomorphic compared to the apes, which is the converse of what has usually been thought on the basis of morphological traits. However, the similarity between the urines of apes and of human infants is certainly far from complete. Thus the histidine contents are not particularly low in infant urine, nor is β -alanine found frequently.

The last point which should be mentioned concerns the great variability of the urinary excretion patterns observed between different individuals of the same species of apes.

As pointed out by Schultz ('51) and other authors, the intra-specific variability in at least some morphological traits in apes is as great as or greater than in man. Our data suggest that the same may be the case for the urinary excretion patterns, at least among chimpanzees. More data would, however, be necessary to establish this point.

SUMMARY

A comparative study of the excretion rates of the urinary amino acids has been carried out in chimpanzee, gorilla, orang-utan, and gibbon. The techniques of paper chromatography have been used. The data obtained can be compared with known excretion rates of the corresponding substances in man. The comparisons reveal very striking differences between man and apes. Human urines contain much more creatinine and histidine than do apes' urines. On the contrary apes excrete much more glutamic and aspartic acids and β -alanine. Differences between the excretion rates in the several ape species are also present, but they are relatively minor compared to the differences between ape and man. Individual differences in the patterns occur within the apes, at least among chimpanzees. Our tentative conclusion is that the magnitude of these individual differences among chimpanzees is at least as great as that found among human subjects.

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of Virginia. We gratefully acknowledge the excellent technical assistance of Mrs. T. Gidaspow throughout the course of this work.

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PLATE 1

EXPLANATION OF FIGURES

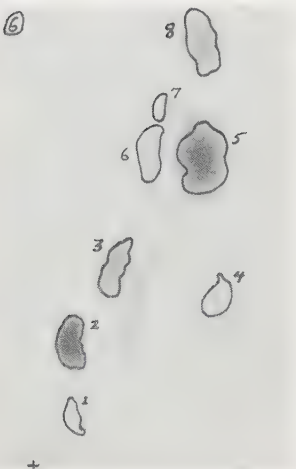
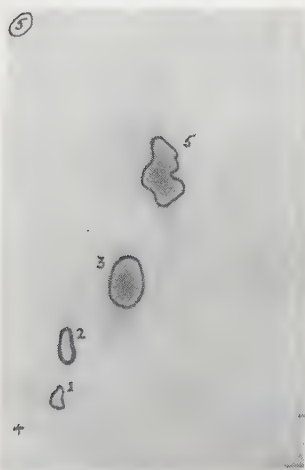
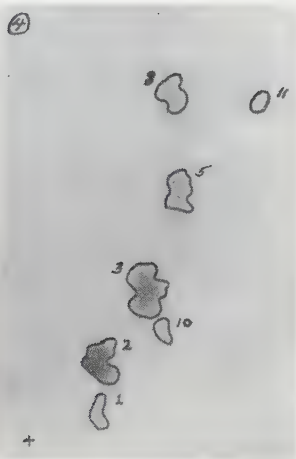
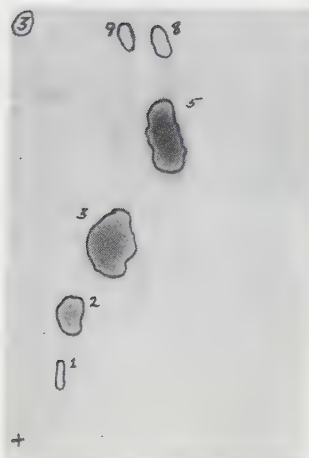
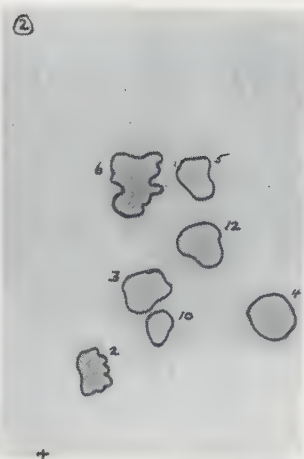
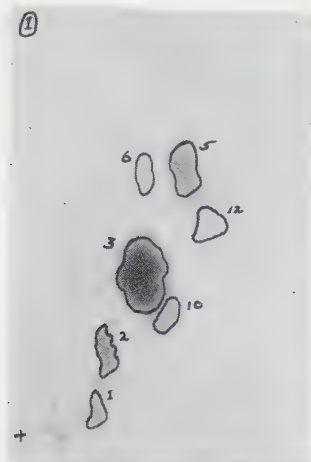
Two-dimensional chromatograms of urinary
amino acids from the great apes.

1-2 Chimpanzee.

3-4 Gorilla.

5-6 Orang-utan.

Legend: 1. Aspartic acid; 2. Glutamic acid; 3. Glycine; 4. Taurine; 5. Alanine
6. Glutamine; 7. Beta-alanine; 8. X; 9. LT; 10. Serine; 11. Valine; 12. Threonine.



THE MEASUREMENT OF CRANIAL SHAPE

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FOUR FIGURES

INTRODUCTION

Variability in the form of the cranial vault has long been of interest to the physical anthropologist. Students of human variation, whether concerned with differences due to race, sex, growth, evolution or other factors, have often found it necessary to measure or express the shape of the brain case in some manner. Many have been satisfied with verbal description. Thus the female skull is said to be more "infantile" than that of the male, as in the shape of its frontal bone, which is more "prominent, obtrusive, bulging, convex, vaulted, bubble-like," and so on. It is perhaps unavoidable that such descriptive systems, including "standardized" rating scales, are hampered by subjectivity, drift and the lack of primary standards. When the exact meaning of descriptive phrases is obscure, rigorous comparison is impossible.

As an alternative, a number of workers have developed numerical, *craniometric* expressions of curvature. No evaluation of these methods seems to have been published, however, and when one or the other has been used, the basis of choice has not always been apparent. Under these circumstances, it is difficult to know which method is the most useful, or indeed whether all provide approximately the same information about the form of the vault.

It is the purpose of this paper to compare and evaluate certain of these curvature expressions, and to present a relatively novel approach to the problem—an approach which makes possible the measurement and precise comparison of *shape*, rather than simply curvature.

MATERIAL AND METHODS

The sample was taken largely from the Fels population. One of the females, however, was a Fels employee, as were three of the males; 5 other men were faculty members of Antioch College. All were white, native-born residents of southwestern Ohio; the majority were of northwest European ancestry.

Five indices of cranial form were computed for both the frontal and parietal bones of 100 white adults (50 ♂ and 50 ♀) from lateral skull x-rays in the Fels series. The oc-

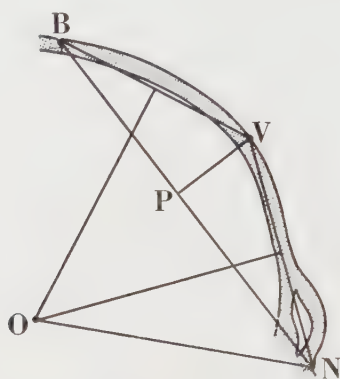


Fig. 1 Landmarks used in obtaining four traditional expressions of cranial curvature. (1) *Curvature angle*: angle BVN. (2) *Chord/arc index*: chord BN/arc BN. (3) *Curvature height index*: perpendicular PV/chord BN. (4) *Radius of curvature*: ON (ON = OV = OB). B, bregma; V, vertex of curvature; N, nasion.

cipital bone was not included because its posterior border (opisthion) cannot be distinguished in the x-ray. The 5 methods, each pertaining to an individual cranial bone in the median sagittal plane, are as follows (see fig. 1):

1. *Curvature angle*. The angle at the intersection of two chords drawn from the ends of an arc to its point of maximum curvature. Increased convexity is reflected in a smaller curvature angle. Martin ('28) describes this measurement and gives a table of racial averages. More recently, the method was employed by Woo ('49).

2. *Chord/arc index* ($100 \times \text{chord/arc}$). The index value decreases as the curvature increases. Mochi ('07) used this index, as did Morant ('27), Weidenreich ('43, '45, '51), and others.

3. *Curvature height index*. The ratio of chord length to the greatest perpendicular distance from chord to arc ($100 \times \text{perpendicular/chord}$). In this case, a higher index indicates a more arched bone. Thomson ('15), Morant ('24, '27), Keith ('31), Weidenreich ('43, '51) and Woo ('49) are among those who have applied this expression.

4. *Radius of curvature*. The radius of a circle drawn through the vertex of the arc and its two terminal points. The dimension becomes shorter with more pronounced bulging. Broca (1874) and Mollison ('04) described instruments which make it possible to measure the radius of a bone in an articulated skull. In the present study the radius was computed by erecting perpendicular bisectors from the chords drawn to obtain the curvature angle. The distance from the point of intersection of these perpendiculars to the vertex of curvature or to either end of the arc is the expression of curvature. Size must be considered, however, since bones of identical shape but different size will not have the same radius of curvature. Pearson suggested a formula which was said to give a close approximation to the radius of curvature corrected for chord length, thereby taking bone size into account. The formula was used by Tildesley ('20), Pearson and Davin ('24), Morant ('27), Pearson and Woo ('35), and others. In the present material the radius was corrected for chord length through use of the technique of partial correlation.

5. The 5th expression, which may be called the *shape index* method, was suggested to the writer by Dr. S. M. Garn of the Fels Institute, and is similar to the method for determining "type contours" used by the University of London Biometric Laboratory (Benington, '11). The technique is an expansion of the curvature height index, and employs the principle that the accuracy of an index increases as the segment of the arc to which it refers decreases. Nine equally-spaced perpendi-

culars are erected from the chord of a single cranial bone to the outer table of this bone (fig. 2). Expressing these perpendiculars as percentages of the chord effectively eliminates the factor of size (making morphological comparison possible, for instance, between the cranial bones of an infant and those of an adult). Measurement was facilitated by photographing a grid on which each perpendicular had been calibrated in percentages of the base line (chord). The negative was then mounted in an enlarger, and projected on a horizontal x-ray

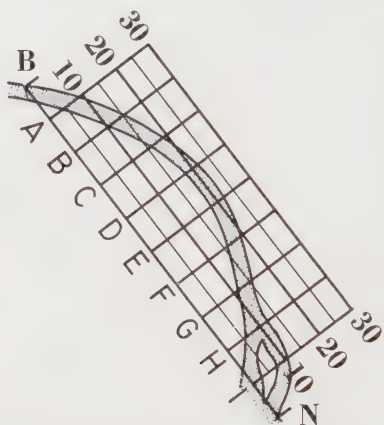


Fig. 2 *Shape index method.* Grid shown superimposed on individual cranial bone (frontal) in lateral skull x-ray. Base line coincides with nasion-bregma chord. Heights of nine perpendiculars (A-I), expressed as percentages of the base line, are read directly from the grid.

illuminator. The x-ray to be measured was adjusted so that the frontal or parietal chord (drawn with pencil on the print) coincided with the base line, and the grid was focused so that the perpendiculars were properly aligned. The percentages were then read directly from the grid.

A plastic T-square was used to construct perpendiculars. Straight line distances less than 10 cm were measured with vernier calipers, and recorded to the nearest 0.1 mm. A metric ruler was used for distances over 10 cm, and was read to the nearest 0.5 mm. Arcs were measured with a steel tape to the

nearest millimeter, and angles were determined with a protractor calibrated to 0.5 degrees.

RESULTS AND DISCUSSION

Summarizing values for the first 4 methods are presented in table 1. All of these indicate that for each sex the frontal bone is more arched than the parietal, and further, that the female frontal is more convex than that of the male.

TABLE 1
Four measurements of cranial curvature for 100 white adults

SEX	BONE	CURVATURE ANGLE			CHORD/ARC		
		Mean	S.D.	S.E.	Mean	S.D.	S.E.
50 ♂	Frontal	130.2	4.3	0.6	87.0	1.6	0.2
	Parietal	130.9	3.9	0.6	89.3	1.5	0.2
50 ♀	Frontal	127.9	4.1	0.6	86.9	1.8	0.3
	Parietal	131.9	4.1	0.6	89.8	1.7	0.2
SEX	BONE	CURVATURE HEIGHT			RADIUS		
		Mean	S.D.	S.E.	Mean	S.D.	S.E.
50 ♂	Frontal	23.1	2.2	0.3	80.6	5.6	0.8
	Parietal	22.6	2.0	0.3	86.4	6.4	0.9
50 ♀	Frontal	24.3	2.2	0.3	73.3	4.1	0.6
	Parietal	22.3	2.2	0.3	83.6	5.7	0.8

Intercorrelations were computed to determine the extent of relationship among these methods. Each was compared with the other three for each bone and separately for each sex. Although it was the purpose of this part of the work to compare methods, and thus it was theoretically justified to combine the sexes, the difference in correlation was tested, using Fisher's Z transforms (Fisher, '48), and it was found that none of the sex differences in intercorrelations was statistically significant. Next the average r was determined, again using Z transforms, and this "mean r " for each method and

for each bone is presented along with the intercorrelations in table 2.

It is evident that the intercorrelations are exceptionally high, with mean values ranging from 0.94 to 0.97. For the frontal and parietal arcs of white adults, and with the possible exception of the chord/arc index, all 4 methods yield practically the same (yet not directly comparable) information.

An examination of figure 1 makes it clear why this is true. Martin ('28) considered the radius of curvature to be superior to the other measurements, and Woo ('49) preferred

TABLE 2
Intercorrelation of curvature measurements: 100 white adults

	CURVATURE ANGLE		CHORD/ARC		CURVATURE HEIGHT ¹		RADIUS ²		MEAN \bar{r}
	Fr.	Par.	Fr.	Par.	Fr.	Par.	Fr.	Par.	
C. Angle	...	...	0.88	0.96	0.97	0.99	0.99	0.99	0.97
Chord/Arc	0.88	0.96	...	...	0.93	0.97	0.88	0.96	0.94
C. Height ¹	0.97	0.99	0.93	0.97	...	...	0.94	0.97	0.97
Radius ²	0.99	0.99	0.88	0.96	0.94	0.97	...	...	0.97
Mean \bar{r}	0.96	0.98	0.90	0.96	0.95	0.98	0.95	0.98	...

¹ Corrected for chord length (partial correlation).

² Reflected.

the curvature angle to the curvature height index because it "more nearly approaches the curvature" of the bone. Figure 1 shows, however, that all three respond to the relative positions of the same three points: the two ends of an arc and its vertex of convexity. The slightly lower intercorrelations of the chord/arc index are probably due to the fact that it is based on the relationship of chord and arc, rather than on the three points just cited.

Martin ('28) and Weidenreich ('43, '51) remark that the chord/arc index may be grossly misleading when there are sizable local protuberances such as supraorbital ridges, and Weidenreich ('51) notes that this is also true of the curvature

height index. Morant ('27) makes the same point in regard to the radius of curvature (and uses the chord/arc index as a preferable substitute). These observations, of course, apply equally to any similar measure which is calculated to encompass irregularities of curvature in a single term. If the shape of a cranial bone were that of a true arc, any of the traditional methods would be satisfactory. However, since this condition does not exist, they must in many situations be inadequate. The shape index method, which avoids this difficulty, will now be considered.

Table 3 presents the means and standard deviations for the lengths of the 9 perpendiculars expressed as percentages of the chord. For visual examination or comparison a contour diagram may be constructed from these data by drawing a line through the 9 points at the specified distances from the chord. Both the greater curvature and the location of the increased convexity of the female frontal bone will be immediately evident, and it will be seen that the "infantile" appearance is not merely a result of the lesser development of the frontal sinus, as has sometimes been suggested.

The dimensions of an individual bone may be compared with group means obtained by the shape index method. In this regard, lateral skull x-rays (fig. 3)¹ of two artificially deformed skulls (Adena ♂ and ♀, adult)² are illustrative.

¹ An x-ray procedure suitable for dried crania does not appear to have been previously described in the anthropological literature. The method employed in this study is therefore presented below, and is compared with data kindly supplied by Dr. H. V. Meredith of the Iowa Child Welfare Research Station, and by Dr. W. S. Cornwell of the Eastman Kodak Company, each of whom reports satisfactory results with the procedure shown.

SOURCE	X-RAY FILM	CASSETTE	KV	Ma.	EXPOSURE	DISTANCE
					(sec.)	(inches)
RWY	Dupont Xtra Fast 508 Medical	Eastman X-ray Exposure Holder	97	75	1.2	72
HVM	Kodak Blue Brand Medical	Patterson Fluorazure	53	25	1.0	60
WSC	Kodak No-Screen Medical	Kodak X-ray Exposure Holder	85-90	10	6.5-16.0	72

² Adena ♂, no. 3104/45, B 18, Cowan Creek Mound, Ohio. Adena ♀, no. 7-13, B 13, Wright Site, Kentucky (cf. figs. 14, 26, Webb and Snow, '45).

TABLE 3

Shape index method: Means, standard deviations, and comparison of deformed skulls

MEASUREMENT	NINE PERPENDICULARS (PERCENTAGE OF CHORD) ¹									CHORD ²	ANGLE AT BREGMA
	A	B	C	D	E	F	G	H	I		
♂ Frontal mean	8.1	14.5	19.1	21.7	22.8	22.1	19.3	14.7	11.8	122.1	99.9
S.D.	1.2	1.7	1.9	2.0	2.1	2.3	2.5	1.9	1.6	5.4	3.4
♂ Deformed	10.5	17.0	21.0	23.5	25.0	24.5	21.0	13.5	9.5	131.0	88.0
D/S.D.	+ 2.0	+ 1.4	+ 1.0	+ 0.9	+ 1.0	+ 1.1	+ 0.7	- 0.6	- 1.4	+ 1.6	- 3.5
♂ Parietal mean	8.0	14.9	19.2	21.9	22.3	21.0	17.9	13.3	7.3	130.0	
S.D.	1.4	1.9	2.0	2.0	2.1	2.0	1.8	1.5	1.0	7.9	
♂ Deformed	10.5	18.0	22.0	24.5	25.5	23.5	20.5	15.0	8.0	100.7	
D/S.D.	+ 1.8	+ 1.6	+ 1.4	+ 1.3	+ 1.5	+ 1.3	+ 1.4	+ 1.1	+ 0.7	- 3.7	
♀ Frontal mean	8.2	14.6	19.5	22.3	23.7	23.9	21.3	16.0	10.8	115.8	100.2
S.D.	1.0	1.4	1.6	1.7	2.0	2.3	2.4	2.1	1.7	5.3	3.3
♀ Deformed	10.5	16.5	20.0	22.0	23.0	21.0	17.0	11.5	9.0	120.6	87.0
D/S.D.	+ 2.3	+ 0.6	- 0.3	- 0.2	- 0.4	- 1.3	- 1.8	- 2.1	- 1.0	+ 0.9	- 4.0
♀ Parietal mean	7.8	14.2	18.7	21.3	22.0	20.8	17.8	13.1	6.9	124.3	
S.D.	1.4	2.0	2.4	2.3	2.2	2.0	1.8	1.5	1.0	6.6	
♀ Deformed	10.5	17.0	21.0	24.5	25.5	24.0	21.5	18.0	10.0	107.8	
D/S.D.	+ 1.9	+ 1.4	+ 1.0	+ 1.4	+ 1.6	+ 1.6	+ 2.0	+ 3.3	+ 3.1	- 2.5	

¹ A - I: Posterior to anterior on each bone.² Uncorrected for x-ray enlargement (4.4%).

The value D/S.D. (or standard score) is $\frac{X - \bar{X}}{S.D.}$.

Application of the shape index method indicated that in both Adena skulls the frontal bone was relatively more arched at the fronto-parietal junction, and relatively less arched in the region of the frontal sinus. The parietal bone, on the other hand, was consistently more curved than the mean configuration of the modern series. These differences may be expressed

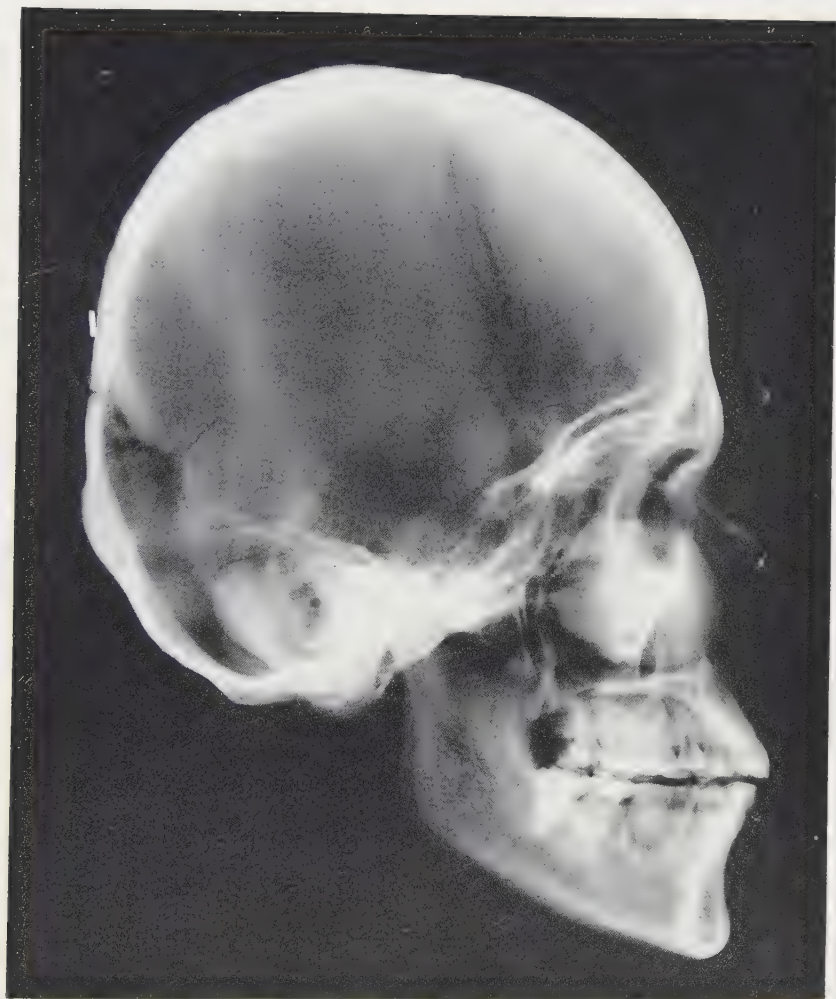


Fig. 3 Lateral x-ray of an artificially deformed Adena skull (adult ♀, no. 7-13). Note pronounced occipital flattening. (Cranial index = 91.0.)

in terms of the standard deviation, thereby avoiding the fallacy of comparisons with a "type." Table 3 presents the S.D. units by which the perpendiculars for the deformed skulls differ from the mean perpendicular lengths (as percentages of the chord) for the 50 individuals of same sex. For problems in which it is desirable to have a single expression of total difference, the mean S.D. difference (disregarding sign) of the 9 perpendiculars might be useful, although it will not reveal the location or nature of the differences.

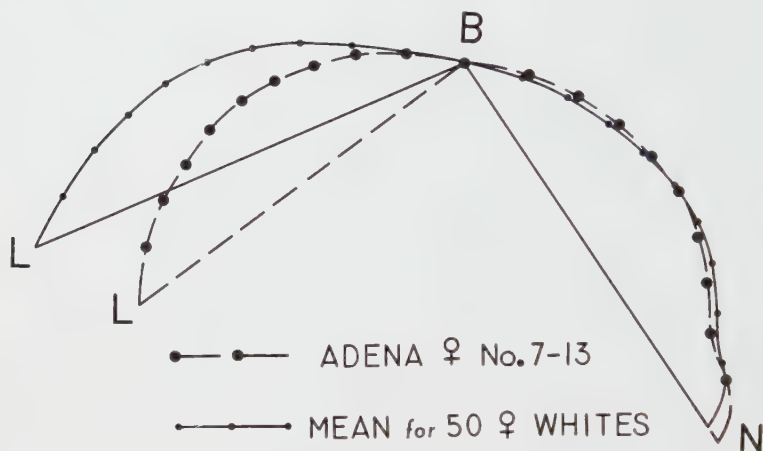


Fig. 4 An application of the *Shape Index* method. Artificially deformed Adena skull (adult ♀) compared with mean dimensions of 50 white adult ♀. Superimposed at bregma and along frontal chord. L, lambda; B, bregma; N, nasion.

By the addition of three further measurements—the lengths of the chords and the degree of the angle between them—the size and spatial relationships of the frontal and parietal bones in the median sagittal plane may also be compared. The results of these measurements for the 100 adults are given in table 3, where they are contrasted with similar data obtained from the x-rays of the deformed skulls. It is apparent that the shortened parietal chords and the reduced nasion-bregma-lambda angle in the latter are well beyond the normal limits derived from the unshaped bones. Figure 4 illustrates these differences for the female crania.

If comparison of these racially unrelated skulls were justified, it might be concluded that part of the Adena deformation was taken up by a spatial reorientation of individual bones, and by retarded anterior-posterior growth of the parietal, while growth along the frontal arc was influenced little or not at all. Compensation for these effects presumably took place in other dimensions, such as breadth and height (Webb and Snow, '45; Snow, '51). Ewing ('50) and others have found that the deformation of occipital flattening affects largely the rear portion of the head. These observations, furthermore, are consistent with studies which have emphasized the relative developmental independence of individual cranial bones.

CONCLUSION

There is an increasing tendency in physical anthropology to avoid all-purpose measurements, and to hold that measures should be designed to fit specific problems (commentary by Kaplan, '50; Washburn, '53). However, in certain areas, such as race and the comparative morphology of the hominids, a number of investigators may independently contribute material; thus some degree of standardization becomes necessary (Neumann, '41). From this viewpoint, it is believed that the shape index method described herein supplies a suitable means for the specific problem of quantifying the assessment of cranial shape. The method is now being used in a roentgenographic study of age changes in cranial morphology.

Krogman ('51) has emphasized the perennial lack of agreement on a base line for the superimposition of skull tracings. Significantly enough, although 20 previously suggested planes are listed, none refers to the individual bone. Some 30 years ago Pearson and Davin ('24) wrote that "anatomically it would be wise never to take a measurement on the skull which extended beyond the limits of a single bone." While this may be an excessive generalization, recent studies (Moss, '54; and esp. Baer, '54) have shown that the individual bone comprises the unit of growth in the brain case. It is hoped that the sug-

gested method will serve as a contribution to studies which are concerned with variation in the form of individual bones.

SUMMARY

1. Five measurements of cranial curvature were taken on the frontal and parietal bones of 100 white adults in the Fels lateral skull x-ray series.

2. Mean intercorrelations of 4 traditional methods ranged from 0.94 to 0.97.

3. These methods are essentially similar; their utility is reduced, however, when curvature varies considerably from a true arc.

4. An additional method for measuring cranial morphology is described and applied to deformed Adena and to normal white crania.

5. This *shape index* method may be used to express the shape, size and angular relationships of individual bones.

ACKNOWLEDGMENTS

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NOTE ON THE MORPHOLOGICAL STATUS OF THE SWANSCOMBE AND FONTÉCHEVADE SKULLS

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FOUR FIGURES

The Swanscombe skull

In the course of investigating the Saldanha skull comparisons have been made with a great number of cognate fossil types, using the Rhodesian skull as a sort of standard by which to measure his relative status. As the latter has sapient as well as Neandertal affinities, the Swanscombe and Fontéchevade crania, which are generally regarded as predominantly sapient but with definite leanings in a primitive direction were included in the survey. There was an added interest in doing so, since this seeming paradox of finding Early Palaeolithic Europeans to be of more modern than archaic shape has not been repeated in South Africa, where the evidence from the Hopefield site, in the author's opinion (Drennan, '54), is strongly presumptive that it was a paleoanthropic type of man who practiced the Hand-axe culture.

The author proposes to bring forward some evidence, particularly about the Swanscombe skull, which seems to dissolve the paradox and show that this skull, and possibly the Fontéchevade specimen as well, can be given a much more primitive status than they have at present. At any rate the evidence and arguments therefrom fully justify the scepticism regarding the morphological status now given to the Swanscombe skull which Oakley ('52) has so well expressed.

In his excellent description of "The Form of the Swanscombe Skull" Morant ('38) has made available for compara-

tive purposes an "actual size" drawing of this skull. When the outer sagittal contour of the parietal and occipital bones, the only two that are available, are superimposed on the standard contour of these two bones of the Rhodesian skull, the latter drawn also by Morant ('28), there is a remarkably close correspondence. So much is this the case that the cardinal points of the skull, the bregma, lambda, opisthion and basion practically coincide, and if one allows for the small

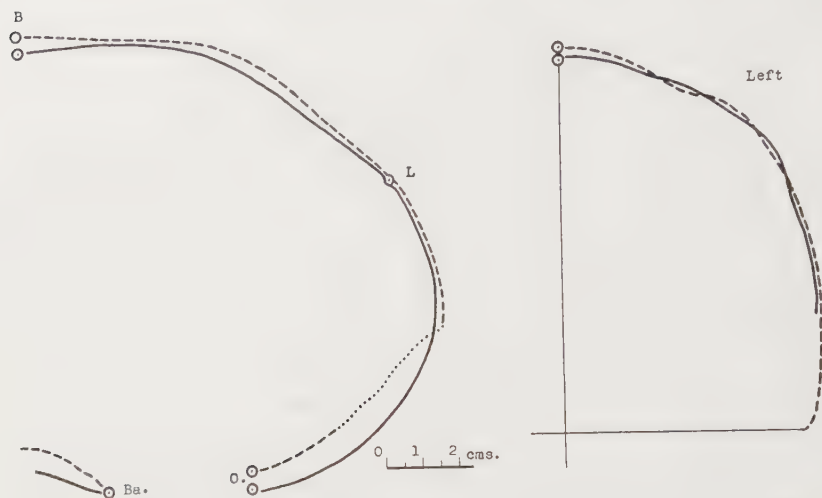


Fig. 1 Tracing of Morant's drawings of the sagittal and transverse contours of the Swansecombe skull—continuous line, compared with his standard drawings of the outlines of the Rhodesian skull—broken line, oriented by approximation of bregma, lambda, opisthion and basion, B, L, O and Ba. respectively.

degree of arbitrariness with which Morant points out he was obliged to fix several of his "points," one may say that the two contours are identical (see fig. 1).

The same is true for the transverse contours, which, apart from showing that the vault of the Swansecombe skull is slightly lower and flatter than that of the Rhodesian, are quite coincident, share the same span of the parietal bones, and agree in having their greatest width low down (see fig. 1).

If this exceedingly close correspondence in the shape and dimensions of the two cardinal contours of these skulls does

not argue for a significant morphological relationship, then all anthropological argument that is based on form and measurement must lose its meaning.

This being so, one can deduce that the cranial capacity of that part of each skull which is circumscribed by these two contours must have been very similar to the corresponding capacity of the other skull. As we happen to be considering the major portion of each cranium, it almost follows that the total cranial capacity of each of these skulls cannot be expected to show much of a difference. This is confirmed by Morant's calculated approximation of 1325 cm^3 for the Swanscombe skull and Keith's figure of 1305 cm^3 for the Rhodesian skull, this latter figure having been arrived at by measuring the amount of water displaced by the Rhodesian endocast.

An incomplete endocast is available for the study of the interior of the Swanscombe skull, and judging by the fine natural size drawings of it used by Le Gros Clark ('38) to illustrate his account of this cast, it provides a good deal of very illuminating information. Everyone now knows the pitfalls that beset the unwary, if he attempts to read the riddle of the convolutions of the human brain from their imprints on the endocranium.

Nevertheless by using standards for measurement as laid down by Kappers ('29), and developed and put into practice by Weidenreich ('36), it is possible to use them to supplement what has been learned from the outside of the skull. Such may in fact be more informative about the status of a particular skull than the outside of the skull can be, for they express the changes of size and proportions that mark the human advances, and they are not complicated by adventitious structures such as brow-ridges etc.

In this direction, according to Le Gros Clark's account, the Swanscombe endocast suggests that the brain of this individual was small, slightly flattened and angular in contour. In some features there appeared to be a retardation in development. In particular the occipital poles lack the "fullness" of both sapient (see fig. 2) and Neandertaloid endo-

casts. There is also a depressed area in the post-parietal region, and the temporal lobes appear to have been specially narrow. On the other hand there is a prominent bulging in the post-temporal region.

Le Gros Clark expresses the opinion that each one of these non-sapient features may be seen occasionally in a modern endocast, but I doubt if any modern endocast would show all of them in the way the Swanscombe endocast happens to do. The important thing to note, however, is that the Rhodesian

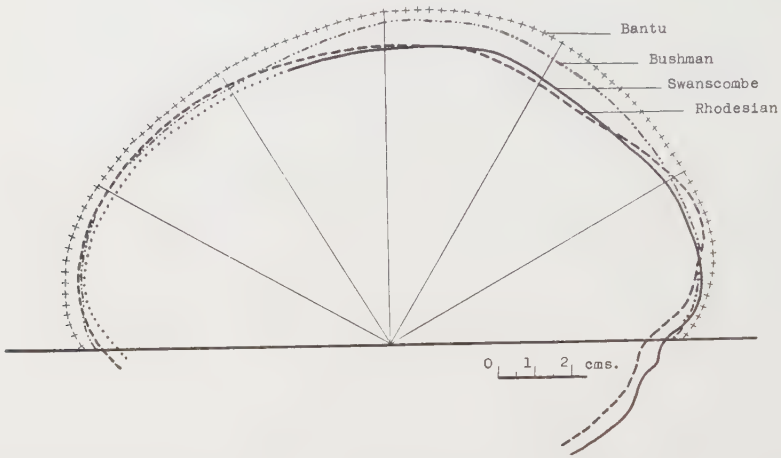


Fig. 2 Contour drawings of the endocasts of the Swanscombe skull, compared with those of the Rhodesian, a Bushman and a Bantu, all centered and oriented on the standard subcerebral plane.

endocast shows the same primitive features as the Swanscombe endocast with one exception. The one exception is in connection with the occipital poles, which are quite bulging in the Rhodesian cast (see fig. 2), whereas in the Swanscombe endocast they are primitive and undeveloped as in the Saldanha endocast. Both endocasts, however, have this in common in the occipital region, that they both show the "fictitious" lunate or simian furrow.

A short metrical comparison between the two endocasts shows that the cerebral elevation of both casts is practically

identical and that both are considerably lower than the Bushman and Bantu contours shown in figure 2. Moreover the areas enclosed between their respective cerebral contours and their subcerebral lines are very similar, when measured with a planimeter.

The author contends, therefore, with regard to both skull and endocast, that if all the resemblances between the Swanscombe and Rhodesian fossils are to be regarded as coincidence and not sufficiently significant to differentiate Swanscombe from *Homo sapiens*, then there would appear to be very little justification for any separation of Rhodesian man himself from modern man.

In view of the facts which have been adduced to justify a comparison between the Swanscombe and Rhodesian skulls, it might appear strange that Morant, who wrote the standard description of the Rhodesian skull and had obvious leanings towards assigning the Swanscombe skull to the Neandertaloid category, did not include the Rhodesian skull within his purview. The reason for this is quite clear, however, and this latter skull was only excluded because Morant considered it belonged to a male, whereas he assumed that the Swanscombe skull had belonged to a female. He therefore limited his comparative material to presumably female types. It must be stated, however, that the sex of some of the types he used for comparison, for example the Steinheim skull, is a very doubtful quantity.

Now the risk of making a mistake in the sexing of a skull belonging to a race whose sexual features are known is quite considerable, because of the degree of overlap of both metrical and non-metrical sex features. The error must be much greater in dealing with types whose sexual characteristics are quite unknown.

As a result, comparative statistics which do not take this into account may be greatly vitiated. Morant's conclusions have suffered considerably from his having ignored the necessary precautions in this direction.

When Morant compared the dimensions of the Swanscombe skull with those of quite a big sample of British female skulls, he considered that the comparison "failed to disclose any feature of the fragmentary Swanscombe cranium which can be supposed to differentiate the prehistoric individual from the existing species of man, and very few features which could be considered at all peculiar if observed in a modern cranium."

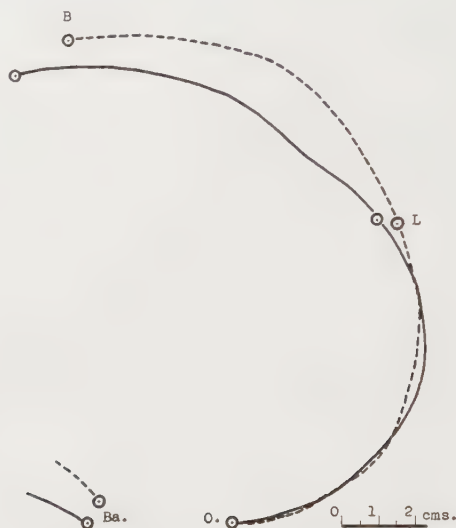


Fig. 3 Contour of the Swanscombe skull compared with the type contour of 87 female sapient skulls, after Morant ('38).

The first part of this contention may be correct from the statistical point of view, but it is questionable that a skull belongs to a group if most of its characters just fall within the limits of variation of the group in its direction. It also offends the author's sense of morphological similarity to say that the graphic form which his results for the British females take is at all like the contour of the Swanscombe skull (see fig. 3). If it be assumed that the sex of the Swanscombe skull is male, which it may well be, then the contour of this skull remains the same, but the contour of British males would

quite outspan that of the corresponding females. It becomes then just a question of sexing, that is to say, a matter of chance, as to whether the Swanscombe skull is, or is not in the sapient category, judging by this sort of comparison.

Nor does the author agree with Morant's second contention that there is no feature in the two bones which helps in the differentiation. It is very suggestive of a Neandertaloid alignment that the Swanscombe occipital bone should have the absolutely and relatively large breadth which is one of the most salient characteristics of Neandertaloid skulls in general and of the Rhodesian skull as well. It appears that a very broad occipital occurs in British skulls with an expectancy of 1 in 5000, but this single abnormality does not have any significance by itself. It is different in the Swanscombe skull where there is an accumulation of primitive features that Morant has had to go to great length to discount.

In his second major comparison Morant has limited his comparison to the two bones that are available. These were compared with the corresponding bones of the sapient female skulls, and with the Steinheim, Spy II, *Pithecanthropus* and a young gorilla skull. The object of the comparison was to see whether other human crania, which are clearly distinguished from the *Homo sapiens* group could be so distinguished, if only two bones in each case had been available.

His results indicate that the metrical characters of the two bones do not distinguish either the Swanscombe or the Steinheim skull from modern man (or rather woman). They also reveal the significant fact that these two skulls are very similar, and Morant considers that it is not unlikely that they represent the same Acheulian group.

There is this important difference, however, that the Swanscombe skull is further removed from the sapient type and nearer to the Neandertal type than the Steinheim skull, at least in respect of the two bones under comparison.

Morant has also proved that, whilst the Rhodesian skull resembles "the modern racial types rather more closely than

the La Chapelle skull does," both the Rhodesian and the Neandertal skull are "more closely related to one another than either is to modern man." This closer approach of the Rhodesian to the Neandertal than to the sapient type is analogous to that which Morant establishes for the Swanscombe skull, to the extent that the Swanscombe skull is closer to the true Neandertal, on the evidence available, than is the undoubtedly Neandertaloid Steinheim skull.

Morant's mathematics would seem therefore to prove that the Swanscombe skull is more Neandertaloid than sapient, and to support the author's present contention in the same direction.

The Fontéchevade skull

In light of what has been said about the status of the Swanscombe skull, it becomes necessary to give some consideration to the Fontéchevade fossil. There is no doubt that, limited as the remains of both these fossils are, they nevertheless have several very significant features in common, but they also have a few differences which may be equally meaningful. Apart from this, the features shown by each are partly sapient and partly Neandertaloid, and, as indicated in connection with the Swanscombe specimen, there is room for a considerable difference of opinion as to which of the two tendencies is the more dominant.

Vallois (Boule and Vallois, '52) considers that the sapient features of both skulls stand out more prominently than the Neandertaloid characters, and he includes them both in his pre-sapiens group. Clark Howell ('51) on the other hand has contended that there is no material difference between the morphology of both the Swanscombe and Fontéchevade skulls and that of the early Neandertals.

Reasons have already been given for considering that the Swanscombe, so far as one can judge from the two available bones, has sapient and Neandertaloid features in about the same proportions as the Rhodesian skull. That is to say, it is more Neandertaloid than sapient.

In the author's opinion the proportions differ to a certain extent in the Fontéchevade skull. Both share the following primitive and for the most part Neandertaloid features: skull bones which are unusually thick but devoid of muscle markings, great occipital or bi-asterionic width, and a low, wide span of the parietal bones. The details of these and other more sapient features are fully set out and discussed by Vallois ('49). Only two of the differences will be referred to here.

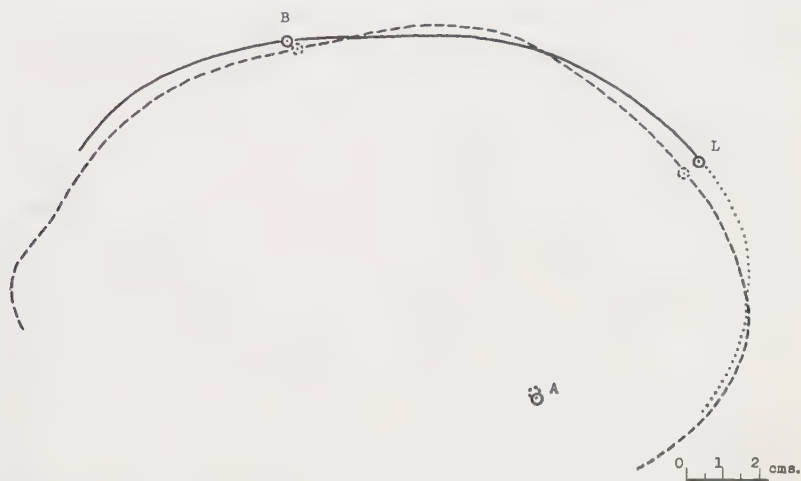


Fig. 4 Contour of Fontéchevade skull, after Vallois ('49) — continuous line, compared with the contour of a cast of the Le Moustier skull, oriented by approximation of bregma, lambda, and asterion, B, L and A respectively.

The cranial capacity of the Fontéchevade skull has been estimated by Vallois to lie somewhere between 1450 and 1500 cm³. This is an unexpectedly high figure for a somewhat primitive skull, and it seems to indicate that it might be pre-Neandertaloid rather than pre-sapient, for the pure Neandertals had for the most part biggish brains.

On the other hand the Swanscombe skull must have had a relatively small brain, and this aligns it more with the Rhodesian.

There is another feature of the Fontéchevade skull which aligns it also with the true Neandertals rather than with sa-

pient types. This is the sagittal contour of the skull, which seems to be very similar to several Neandertal contours in that it shows an elongated, rather flat curve; the usual sapient contour is shorter, more elevated and rounder.

In figure 4 the contour of a cast of the adolescent Le Moustier Neandertal is superimposed on the available part of the contour of the Fontéchevade cranium. As a guide for orientation an approximate coincidence of three "points" on each skull, bregma, lambda and asterion has been chosen.

The Le Moustier cranium has been chosen for comparison for two reasons. The first is that taking the Le Moustier contour as being reasonably similar to an adult Neandertal, I show that the Fontéchevade contour is not very different from it, certainly not nearly so different as it is from the contour of the average modern skull.

Another reason for taking the Le Moustier Neandertal is that in so far as he has a juvenile or paedomorphic shape of head, it is with such a shape that the Fontéchevade skull is in conformity. If Vallois is correct in considering that the brow-ridges could at the most have been only feebly developed, then, Neandertaloid to the extent that he is otherwise, Fontéchevade man must have been at the same time a pedomorph. On the other hand Swanscombe man (and the term is used advisedly for the prejudice he may have suffered and may still suffer in status by the usual assumption as to his femininity) in his resemblance to Rhodesian man is to that extent a gerontomorph.

To the author's way of thinking therefore, it seems reasonable to postulate that in the so-called pre-sapiens group there is another example of the interplay of the principle of gerontomorphism (Swanscombe) and pedomorphism (Fontéchevade), which recurs again and again in the human phylum, and persists in *Homo sapiens* in those primitive and quite Neandertaloid remnants of the past, the one expressed in the Australian and the other in the South African Bushman.

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MULTIPLE INFRAORBITAL, ETHMOIDAL, AND MENTAL FORAMINA IN THE RACES OF MAN

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INTRODUCTION

In two recent papers, Schaefer ('54) and Schultz ('54) have discussed the numerical variability of infraorbital foramina in primates. Schaefer included a small sample of human skulls consisting of 45 European, 28 Melanesian and American Indian, and 7 Viking skulls. On the basis of this material he concluded that differences in the number of infraorbital foramina are not significant, since they are not greater than numerical differences between the right and left sides or between the two sexes, and that they are probably due to the small size of his sample.

However, Schaefer's sample was much too small to warrant a conclusion regarding the significance of the numerical variability of infraorbital foramina in human races. It is true that the previously published data (Gruber, 1874; Le Double, '06, 177 with bibliography; Lotric, '53; Adachi, '04, 458-459) though not analyzed by Schaefer, are not very suggestive of racial differences, but these data are either too limited or the exact provenience of some of the material is not clearly stated. In the present study larger samples of various racial groups were used. Moreover, the analysis was extended to a study of ethmoidal and mental foramina in order to find out whether or not there exists any correlation between them and infraorbital foramina.

MATERIALS AND METHOD

Gruber (1874), Le Double ('06), and Adachi ('04), who have given the most detailed description of the variation in size, form, and position of infraorbital foramina and the typology of the canals connecting them with the interior of the orbit, have rightly called attention to the pitfalls in recognizing secondary infraorbital foramina and distinguishing them from simple nutrient foramina. In the present study, all secondary foramina were probed with a coarse hair. No attempt was made to separate the sexes. A total number of 8,836 skulls of various racial groups in the American Museum of Natural History was used for the study of infraorbital foramina. Ethmoidal foramina were studied in 2,386 skulls of this total sample, and mental foramina in more than 1,963 mandibles (3,987 sides) partly belonging to this sample and partly in isolated specimens derived from the same racial groups. The observations on infraorbital foramina are given in table 1. The finding of previous studies according to which the number of infraorbital foramina ranges from 1 to 4 on one side is confirmed by the present data. In view of the rarity of 4 foramina, it should be mentioned that 4 foramina were found by the writer in 11 cases (Yugoslavians 1, Alpines 3, Melanesians 1, Indonesians 2, Washington Indians 1, Northwest Coast Indians 2, Mexicans 1). A single case of 5 foramina recorded by Gruber (1874, 17) is not confirmed by the present data nor has it been found by any other author.

Racial differences of infraorbital foramina

On the basis of these data, the following evaluation may be made of Schaefer's interpretations. Schaefer's average number of infraorbital foramina (right and left as well as the sexes not separated) ranges from 1.09 for Europeans to 1.14 for Melanesians and American Indians combined. Since this difference of 0.05 is smaller than that between right and left in identical sex groups (ranging from 0.00 to 0.09 thus giving a spread of 0.09) and that between the two sexes (ranging

TABLE 1

Incidence of infraorbital foramina according to tribal and racial groups

TRIBE OR AREA	NO. OF SKULLS EXAMINED	MULTIPLE FORAMINA	AVERAGE NUMBER OF FORAMINA		
		% of cases	Left	Right	Both sides
Eskimo	540	21.30	1.15	1.12	1.13
Northwest Coast	477	33.12	1.25	1.19	1.22
Washington	159	25.16	1.20	1.18	1.19
Plains	33	27.27	1.24	1.21	1.22
Northeast	147	17.69	1.13	1.10	1.11
Southeast	35	28.57	1.11	1.17	1.14
Southwest	666	11.41	1.08	1.04	1.06
Utah	157	24.84	1.16	1.14	1.15
Aleutians and Siberians	26 14	12.50	1.15	1.07	1.11
Mexico	500	14.20	1.10	1.08	1.09
Andes	1201	20.32	1.13	1.12	1.12
Antilles	35	11.43	1.11	1.06	1.08
Tropical Forest	16	12.50	1.12	1	1.06
Asiatic Mongoloids	135	25.18	1.15	1.17	1.16
Malay Peninsula and Indonesia	155	27.10	1.22	1.19	1.20
Micronesia	25	16	1.12	1.08	1.10
Melanesia	327	26.60	1.16	1.19	1.17
Polynesia	136	20.59	1.13	1.12	1.12
Australia	44	15.91	1.14	1.04	1.09
European Nordics	6	6	1.17	1	1.08
Alpines	2389	15.19	1.11	1.08	1.09
Mediterraneans	352	15.62	1.12	1.08	1.10
Eastern and South- eastern Europe	128	17.19	1.11	1.16	1.13
Asia Minor and Near East	241	12.45	1.08	1.06	1.07
India	88	12.50	1.14	1.08	1.11
Egypt and neighbor- ing North Africa	470	9.79	1.07	1.05	1.06
African Negroids	334	6.29	1.04	1.05	1.04

from 0.03 to 0.09 thus giving a spread of 0.06), Schaefer considers the numerical variability of the racial groups used as non-significant. However, in the present larger sample the average number of infraorbital foramina (right and left not separated) ranges from 1.04 to 1.22. The difference of 0.18 is not only greater than Schaefer's racial, right-left, and sexual differences, but is also greater than the right-left differences of the present sample ranging from 0.02 to 0.17 thus giving a spread of 0.15. The amplitude of this latter range is however greatly exaggerated by the sampling. If the right-left differences in the present material are compared with the size of the samples, it may be seen that in none of the larger samples does this difference exceed 0.05 (ranging from 0.01 to 0.06) and that in those cases in which the difference is greater, the samples are extremely small (Aleutians and Siberians 40 skulls, Americal Tropical Forest 16 skulls, Australians 44 skulls, European Nordics 6 skulls). That this right-left difference poses a problem in itself will be seen later, but for the time being it appears clearly that the racial difference of 0.18 in the number of infraorbital foramina is much greater than any other difference and therefore significant.

When the present material is viewed from the standpoint of racial classification it appears that the largest number of infraorbital foramina occurs among Mongoloids. In this group (American Indians, Asiatic Mongoloids, and Indonesians combined) the average number of infraorbital foramina is 1.15 as against 1.10 among European Whites, and only 1.04 among African Negroids. But in individual groups the average number (on one side) can be as high as 1.25 among the Indians of the Northwest Coast, 1.24 among the Plains Indians, and 1.22 among the Indonesian Mongoloids. The much greater number of infraorbital foramina among the Mongoloids is even more clearly apparent if the percentage of cases with multiple foramina in various racial groups is analyzed. For here again the values for Mongoloids are much higher than those of any other racial group. The maxi-

imum frequency of 33.12% occurs among the Indians of the Northwest Coast, among those of the Southeast it is 28.57%, and among the Indonesians 27.10%. This differs markedly from European Whites in whom multiple infraorbital foramina appear in an average of 15.34% of all cases, and even more strikingly from African Negroids in which the frequency is only 6.29%. The two extremes in the frequency of multiple infraorbital foramina are the American Indians of the Northwest Coast with a maximum and African Negroids with a minimum frequency, the Caucasoids being intermediate. The other racial groups are arranged more or less proximate to these extremes, as can be seen in table 1. The high frequency of multiple infraorbital foramina among the Indians of the Northwest Coast did not escape Oettking in his study of this group ('30, 312, fig. 74; also Schultz, '54, 406) who has called attention to this feature without however giving any statistical data.

While the above distributional differences seem to indicate that the frequency of multiple infraorbital foramina forms a racial trait, the great variability of this feature among American Indians would seem to preclude such a conclusion. Thus, in the Middle American and South American material the average number of infraorbital foramina (right and left not separated) is only 1.09, a value which is much closer to the European average of 1.10 than it is to the general Mongoloid average of 1.15. It is tempting to compare this north-to-south decrease in America with that of the Euro-African continent and to seek as a cause an environmental factor common to both. However, such an attempt would be immediately frustrated by the fact that the southern Mongoloids of Indonesia with their average number of 1.20 and their percentage of 27.10 for cases with multiple infraorbital foramina do not follow the assumed north-to-south cline, and that also the Oceanic Negroids of Melanesia differ from those of Africa by a much higher frequency. In spite of such regional dif-

ferences it would seem however that the trait has some limited racial significance.

That a genetic factor is involved in the development of multiple infraorbital foramina, has been suggested by Schultz ('54, 406 f., fig. 1), who has shown that in 5 skulls from Tierra del Fuego probably belonging to one family group, multiple foramina are present in all cases. The present writer has no skeletal material at his disposal authentically derived from family groups. A study based on x-rays, on the other hand, would face the extreme difficulty of distinguishing between multiple infraorbital and nutrient foramina. In the material used for this study there appeared occasionally significant differences in the frequency of multiple infraorbital foramina between various different neighboring localities. But whether kinship relationships are involved in these local groups is not known. The problem requires further study.

One of the most interesting observations revealed by the present data is the extremely low frequency of multiple infraorbital foramina among African Negroids. This observation assumes an even greater importance in view of the fact that in all cases of *Australopithecus* (*Africanus*, *Plesianthropus transvaalensis*, *Paranthropus robustus*, *Paranthropus crassidens*, and *Australopithecus prometheus*) in which the maxillary part carrying the infraorbital foramen was preserved, no multiple infraorbital foramina were found (Broom, '38, 378, 829; Broom and Schepers, '46, 33; '48, pl. V, 85, pl. VIII, fig. 84; Broom and Robinson, '50, 16; Broom and Robinson, '52, 12; Dart, '49, 191; Schaefer, '54, 20-21). Moreover, Schaefer and Schultz have shown that in spite of the small number of infraorbital foramina in certain races of *Hylobates*, the gorilla, though ranging from 1.46 to 1.59 in the average number of infraorbital foramina according to various authors, is rather close to man in the high frequency of single infraorbital foramina. It would seem difficult not to ascribe some phylogenetic value to these African data comprising fossil and living primates as well as recent man.

Asymmetry of infraorbital foramina

If the above data on the number of infraorbital foramina are viewed with regard to their symmetry on the skull, it appears that in the majority of cases the number is slightly higher on the left than on the right side. This raises the question of whether or not some functional causes are responsible for the number of infraorbital foramina, and if so, whether such functional reasons are also responsible for the numerical variability in the regional or racial sense. It is recognized of course that only through direct inspection on the dissection table would it be possible to find out whether multiple infraorbital foramina give passage more often to a vessel or a nerve. Since however no sufficiently large sample of cadavers of various racial origins is easily accessible, the writer has studied the numerical variability of ethmoidal and mental foramina, in order to find out whether there is any correlation between these latter and infraorbital foramina. The percentages of multiple infraorbital foramina in the samples here used differ slightly from those previously indicated in table 1 because of the smaller size of the samples, but they follow the general pattern of the numerical variability of the larger samples. The observations are contained in table 2.

Ethmoidal foramina

That the numerical variability of ethmoidal foramina is greater than the anatomical conception of variation, has already been pointed out by Del Magro ('52). In a study of 655 human skulls he found that in 49.4% there were 1, 3, or 4 instead of 2 foramina on each side. The present data confirm the numerical variability from 1 to 4 foramina, and in 6 cases even 5 foramina were found (Eburne 1, Utah 1, Bolivian 3, Polynesian 1). Moreover, it appears that those racial groups which are characterized by a larger average number of infraorbital foramina (American Indians, Indonesians, Polynesians, and Melanesians) have also a larger number of ethmoidal foramina than those groups (Hungarians

TABLE 2

Average number of ethmoidal foramina

TRIBE OR AREA	NO. OF SKULLS WITH SINGLE IN- FRAORB. FORAMINA	RIGHT AND LEFT NOT SEPARATED	RIGHT	LEFT	SKULLS WITH SINGLE AND MULTIPLE INFRA- ORBITAL FORAMINA	
					Right e	Left f
Northwest Coast						
of America	359	2.50	2.49	2.52	2.55	2.56
Utah Indians	95	2.42	2.31	2.53	2.39	2.54
Bolivians	417	2.51	2.52	2.50	2.55	2.52
Melanesians	216	2.42	2.40	2.44	2.36	2.46
Indonesians	33	2.36	2.30	2.42	2.29	2.45
Polynesians	45	2.40	2.38	2.42	2.31	2.37
Hungarians	469	2.33	2.33	2.35	2.37	2.35
African Negroids	292	2.28	2.27	2.29	2.24	2.30

TRIBE OR AREA	NO. OF SKULLS WITH MULTIPLE INFRAORBITAL FORAMINA g	MULTIPLE INFRA- ORBIT. FORAMINA % OF CASES h	RIGHT AND LEFT NOT SEPARATED i	RIGHT j	LEFT k
Northwest Coast					
of America	155	30.15	2.60	2.61	2.60
Utah Indians	32	25.20	2.51	2.47	2.56
Bolivians	89	17.59	2.56	2.58	2.55
Melanesians	73	25.26	2.41	2.33	2.49
Indonesians	21	38.89	2.38	2.28	2.48
Polynesians	12	21.05	2.29	2.25	2.33
Hungarians	59	11.17	2.38	2.41	2.35
African Negroids	19	6.11	2.26	2.21	2.31

TRIBE OR AREA	CASES WITH MULTIPLE LEFT INFRAORB. FORAMINA			CASES WITH MULTIPLE RIGHT INFRAORB. FORAMINA			CASES WITH MULTIPLE RIGHT AND LEFT INFRAORBITAL FORAMINA		
	Right and left l	Right m	Left n	Right and left o	Right p	Left q	Right and left r	Right s	Left t
Northwest Coast									
of America	2.70	2.69	2.71	2.47	2.39	2.56	2.60	2.70	2.52
Utah Indians	2.46	2.40	2.53	2.41	2.33	2.50	2.90	3	2.80
Bolivians	2.58	2.63	2.54	2.58	2.61	2.55	2.50	2.41	2.59
Melanesians	2.54	2.54	2.54	2.46	2.29	2.62	2.24	2.16	2.32
Indonesians	2.39	2.44	2.33	2.25	2.17	2.33	2.50	2.17	2.83
Polynesians	2.16	2.17	2.17	2.50	2.67	2.34	2.33	2	2.67
Hungarians	2.43	2.45	2.41	2.40	2.44	2.36	2.25	2.25	2.25
African Negroids	2.12	2.25	2	2.21	2.28	2.14	2.37	2.12	2.62

and African Negroes) which show a smaller number of infraorbital foramina. Although this correlation is not a rigid one, the Indians of the Northwest Coast, who have the largest number of infraorbital foramina, have also the largest number of ethmoidal foramina (2.60), and the African Negroids characterized by the smallest number of infraorbital foramina, have also the smallest number of ethmoidal foramina (2.26) (right and left not separated in the sample with multiple infraorbital foramina cases).¹ Thus it would seem to follow that the same factor which determines the numerical variability of infraorbital foramina, determines also that of ethmoidal foramina. However, individual groups of skulls with multiple infraorbital foramina within the same racial group do not, in all cases, necessarily have also a larger number of ethmoidal foramina than those with single infraorbital foramina (as appears when columns b and i are compared with each other), although this is so in 5 out of 8 samples.

Asymmetry of ethmoidal foramina

The numerical superiority of infraorbital foramina on the left side of the skull is only partly paralleled by the ethmoidal foramina. However, out of 16 samples (cases with single and multiple infraorbital foramina separated), 12 show a greater number of ethmoidal foramina on the left than on the right side and only 4 samples show the reverse condition; or, out of 8 samples with cases with single and multiple infraorbital foramina combined, 6 show a greater frequency of ethmoidal foramina on the left and 2 on the right side, if columns c and j, d and k, and e and f are compared. If the number of ethmoidal foramina (right and left not separated) in cases with multiple infraorbital foramina is studied, it appears that in the 8 existing samples, 5 show a greater frequency of ethmoidal foramina in cases of multiple left infraorbital foramina than in cases with multiple right infra-

¹ In the sample with multiple infraorbital foramina, the Hungarians have more ethmoidal foramina than the Polynesians and the same number as the Indonesians, but this is probably partly due to the small size of the samples.

orbital foramina, and that in one case the number of ethmoidal foramina is equal in both cases, so that here too the tendency of increasing the number of foramina applies to both infra-orbital and ethmoidal foramina (columns l and o). On the other hand, the numerical status of ethmoidal foramina in cases with multiple right and left infraorbital foramina (columns r, o, and l) is inconclusive; and so it is in columns m, n, p, and q, from which it appears that numerical superiority of infraorbital foramina on either the right or the left side does not necessarily imply a numerical superiority of ethmoidal foramina on the same side of the skull. Only in columns s and t does a slight numerical superiority of ethmoidal foramina on the left side appear again in cases with bilateral multiple infraorbital foramina, thus confirming the left-side superiority previously mentioned. Some of the latter observations should however be taken with caution, since by breaking down the original sample into subgroups as those mentioned in some of the above columns, the size of the subgroups is considerably reduced. However it does follow from these observations that, generally speaking, ethmoidal foramina follow infraorbital foramina in terms of their racial distribution and unilateral asymmetry.

Mental foramina

In a recent article on the mental foramen, Ashley Montagu ('54, table 2, p. 511) has published a list of the frequencies of multiple mental foramina in anthropoid apes and various racial or ethnic groups of man based on the existing literature and some of his own observations. Most of the samples used in the present study are considerably larger than those of previous workers. The observations are contained in table 3.

It follows from the combined observations that the numerical variability of mental foramina is much less than that of ethmoidal and infraorbital foramina. Whereas Del Magro in his study of ethmoidal foramina found a deviation from the two-foramina pattern in 49.4%, and the values on the

frequency of multiple infraorbital foramina presented in this paper (table 1) range from 6.29% in African Negroes to 33.12% in the Indians of the Northwest Coast, the frequency of multiple mental foramina ranges from 1.5% in Russians (Gruber, 1872, quoted by Ashley Montagu, '54, table 2, p. 11) to about 10% in Melanesians. A frequency of 16.7% for Negroes surpassing even that of 15.06% for a chimpanzee sample (Simonton, '23, quoted by Ashley Montagu, '54, table 2, p. 11) is certainly not correct and obviously due to the small size (42 sides) of the sample. The present much larger Negro sample (512 sides) gives a value of 8.01% only. And the

TABLE 3

Mental foramina according to tribal and racial groups

	SIDES EXAMINED	CASES WITH MULTIPLE MENTAL FOR.	%	AVERAGE NUMBER OF MENTAL FORAMINA	
				Left	Right
Polynesians	40	5	12.05	1.02	1.05
Melanesians	484	47	9.71	1.09	1.11
Negroes	512	41	8.01	1.10	1.09
Bolivian Indians	92	7	7.61	1.04	1.11
Utah Indians	293	15	5.12	1.04	1.05
Egyptians	830	30	3.61	1.02	1.05
Northwest Coast Indians	607	20	3.29	1.03	1.03
Hungarians	989	29	2.93	1.02	1.04
Washington Indians	140	3	2.14	1.03	1.03

statement of a complete absence of multiple mental foramina in Egyptians (156 sides) (Simonton, '23, quoted by Ashley Montagu, '54) would arouse suspicion even if left unchecked in view of the universal occurrence of multiple mental foramina. A much larger sample of Egyptian mandibles here used (830 sides) gives a frequency of 3.61% of cases with multiple mental foramina, a frequency which is not even particularly close to the minimum values observed. The present Polynesian sample with a frequency of 12.05% is probably too small and thus not very reliable. This lower interracial variability is confirmed by the smaller numerical range of mental foramina in general. Whereas infraorbital and eth-

moida1 foramina vary in number from 1 to 5, mental foramina, according to the present data, vary from 1 to 3 only. Three foramina were found in 16 cases (Melanesians 1, Hungarians 3, Washington Indians 1, African Negroes 10, Egyptians 1).

Table 3 further shows that the racial distribution of mental foramina differs greatly from that of infraorbital and ethmoidal foramina. Thus the African Negroids, who have the lowest frequency of multiple infraorbital and ethmoidal foramina, show a very high frequency of multiple mental foramina, a characteristic paralleled by the Oceanic Negroids. The Indians of the Northwest Coast on the other hand, who figured so prominently in their high frequency of infraorbital and ethmoidal foramina, appear very low on the list of multiple mental foramina. There is a great deal of regional variability among the Mongoloids and Caucasoids listed, without however indicating any particular trend that could be interpreted on environmental grounds.

It is interesting to notice that *Australopithecus* which, as mentioned above, parallels modern Negroids in its small number of infraorbital foramina, does so also in regard to mental foramina by showing multiplicity in a certain number of cases. Thus, one mandible of *Plesianthropus* and one of *Paranthropus crassidens* have 2 mental foramina on one side, and *Paranthropus robustus* has no less than 4 (Broom, '47, fig. p. 14; Broom and Schepers, '46, 94, pl. X, fig. 101; Broom and Robinson, '50, fig. 12, p. 34, pl. V, fig. 20; Broom and Robinson, '52, 5). Speaking of fossil types of man, Warwick ('50, 118) has expressed the opinion that double or multiple mental foramina are found in those types in which the chin was either absent or little developed. An application of this observation to living races of man does not seem to be in any basic conflict with the distributional evidence of multiple mental foramina.

Asymmetry of mental foramina

The discrepancy in numerical variability and racial distribution between infraorbital-ethmoidal and mental foramina

is borne out by the right and left frequency. Whereas infra-orbital and ethmoidal foramina show a greater frequency on the left side, Ashley Montagu ('54, 512) summarizing the situation points out that all previous observers (Akabori,

TABLE 4

Incidence of mental, infraorbital, and ethmoidal foramina according to tribal and racial groups

TRIBES OR RACIAL GROUPS	SINGLE MENTAL FORAMINA		MULTIPLE MENTAL FORAMINA	
	Compared with infraorb. for. (no. of sides)	Compared with ethmoidal for. (no. of sides)	Compared with infraorb. for. (no. of sides)	Compared with ethmoidal for. (no. of sides)
Northwest Coast				
Indians	288	262	24	18
Washington				
Indians	98	90	4	4
Utah Indians	190	182	14	12
Bolivians	46	44	10	10
Melanesians	392	366	80	80
Polynesians	30	28	8	8
Hungarians	830	736	52	50
African Negroes	388	372	68	68
TRIBES OR RACIAL GROUPS	AVERAGE NO. OF INFRAORB. FORAMINA		AVERAGE NO. OF ETHMOIDAL FORAMINA	
	Cases with single mental foramina	Cases with multiple mental foramina	Cases with single mental foramina	Cases with multiple mental foramina
Northwest Coast				
Indians	1.20	1.04	2.51	2.28
Washington				
Indians	1.12	1	2.50	3.25
Utah Indians	1.13	1.21	2.47	2.50
Bolivians	1.11	1	2.75	2.30
Melanesians	1.09	1.17	2.45	2.34
Polynesians	1.13	1.25	2.21	2.62
Hungarians	1.08	1.02	2.34	2.32
African Negroes	1.06	1.09	2.31	2.28

Bertelli, Gruber, Hori, and Le Double) agree that multiple mental foramina are slightly more frequent on the right than on the left side. This result is confirmed by the present data as shown in table 3, with the exception of the Washington and Northwest Coast samples, in which the values are identi-

cal on both sides and the African Negroids in which the average number of mental foramina on the left side is 0.01 higher than on the right, a difference which is however statistically not significant.

The following table 4 shows that the multiplicity of mental foramina is not generally paralleled by a multiplicity of infraorbital and ethmoidal foramina. Out of 8 samples, 4 show a greater number of infraorbital foramina in cases with multiple mental foramina, but in the 4 remaining samples this parallelism is absent; and 3 samples show a greater number of ethmoidal foramina in cases with multiple mental foramina, but in the remaining 5 samples the number of ethmoidal foramina is smaller in the cases with multiple mental foramina. In spite of the fact that by breaking down the original samples into such small subgroups the results become less reliable, a lack of correlation seems the most likely conclusion. It corroborates the findings in regard to numerical variability, racial distribution, and right and left frequencies, in which mental foramina and infraorbital-ethmoidal foramina follow an entirely different course. Such a complete discrepancy seems to indicate that the number of foramina in the facial and mandibular area is determined by entirely different causes.

SUMMARY

The frequency of multiple infraorbital foramina has been studied in a large number of skulls. Some racial differences occur with African Negroids showing the lowest and Mongoloids the highest frequency.

The low frequency of this feature in certain fossil and living African primates as well as recent man in Africa suggests that this phenomenon may have phylogenetic significance.

The number of infraorbital foramina is slightly higher on the left than on the right side. This condition is paralleled by ethmoidal foramina which, generally speaking, follow also the racial distributional pattern of infraorbital foramina.

Mental foramina differ from infraorbital and ethmoidal foramina in their numerical variability, asymmetry, and racial distribution. This complete discrepancy seems to indicate that the number of foramina in the facial and mandibular area is determined by entirely different causes.

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SKIN REFLECTANCE STUDIES IN CHILDREN AND ADULTS ¹

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FOUR FIGURES

INTRODUCTION

The investigation of skin color has come a long way in the past half century. Initially purely subjective, the use of painted chips and colored tiles improved skin color studies, and substituted color-matching for unsatisfactory color description. Reflection colorimetry in turn has completed the transition. With the Hardy Reflection Spectrophotometer (Hardy, '35) or with portable reflection colorimeters of simpler design, it is possible to measure the percentage reflectance of the skin in any portion of the spectrum. Color-matching has thus been replaced by color measurement.

At the same time, increased knowledge of the optical properties of the skin has broadened the theoretical implications of skin color studies. Though a variety of blood pigments, carotene, and the thickness of the skin itself, all contribute to the color of the skin, the bulk of inter-personal and inter-racial differences in skin color are due to differences in melanin concentration (Edwards and Duntley, '39; Garn, '54; Hall et al., '53). And, since melanin concentration in the skin is related to the amount of the enzymes *tyrosinase* and *dopase* (Gordon, '53) and these in turn are under genic control, it follows that

¹ A preliminary account of these studies was presented at the 23rd annual meeting of the American Association of Physical Anthropologists in Yellow Springs, Ohio, March 27, 1952.

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skin reflectance measurements may come closer to measuring the genotype, than might have been suspected.

Edwards and his associates, using the Hardy Reflection Spectrophotometer at the Massachusetts Institute of Technology, have investigated skin reflectance in the entire visible range (Edwards and Duntley, '39a; Edwards and Duntley, '39b) and in the near ultraviolet (Edwards, Finklestein and Duntley, '51). Their investigations which required the intensive study of a small number of individuals have not only established the pigments responsible for skin color, but have shown the influence of various steroid hormones on melanogenesis (Edwards et al., '41; Edwards and Duntley, '49) and have stimulated more recent work on the pigmentogenic properties of adreno-cortical hormones (Hall et al., '53). Lasker, in turn, has investigated larger numbers of individuals, but in more limited sections of the spectrum, and with a simplified reflection colorimeter (Photovolt model 610). His investigations have concentrated on two problems (1) skin reflectance in young individuals of mixed (Mestizo) ancestry (Lasker, '54a) and (2) seasonal changes in skin reflectance in whites (Lasker, '54b). Thus, Lasker's work relates to the genic determinants of skin color on the one hand, and to environmental determinants on the other.

The present investigation, begun in 1953 and still in progress, is concerned with a particular aspect of skin coloration, namely the effect of the internal environment on the reflectance of the skin on several different areas of the body. Through the use of a wide age range (1 to 60 years) and through the inclusion of maturing children and pregnant women, a variety of normal endocrine states are made available for investigation. Moreover, by measuring the reflectance of the areola and scrotum, and by investigating the interrelationships among the various skin areas, new data are made available on how the pigmentary pattern of the skin as a whole responds to altered hormonal status.

METHODS AND MATERIALS

The present study is based upon skin reflectance readings, in the blue end of the spectrum, on a total of 252 men, women and children, most of them participants in the Fels Longitudinal Studies. Except for one set of triplets, all were white, and American-born; all were free from known endocrinopathy or abnormality of the pigmentary system. Besides a division on the basis of sex, further sortings were effected in terms of maturity status rather than age alone. In the case of adult women, those who were pregnant were recorded separately from those who were not pregnant and never had been so. Unless stated otherwise all data refer to the "bright" months of the year, May through October.

The skin reflectance readings include one area ordinarily most exposed to solar radiation (the forehead), two areas generally less exposed (the chest or breast and the upper inner arm), and two areas where melanin deposition is markedly responsive to sex-hormone stimulation (the areola of the breast, and the scrotum). Thus it was possible to determine, for each individual, the "basal" skin reflectance or lightest area, the amount of hyperpigmentation due to solar radiation, and finally the extent of pigmentation formed in response to hormonal stress.

The reflectance readings were made with a Photovolt Model 610 Colorimeter, as described by Lasker ('54a, '54b), and equipped with a blue "Corning" filter. This filter was tested against a quartz blank, using a Beckman DU spectrophotometer, and found to have maximum transmission at λ 380-460 with a peak at λ 420. Since the absorption maximum of melanin is in the near UV, the blue filter afforded maximum discrimination for small variations in melanin concentration. In general, blue filter readings are lower than, but correlate highly with red and green filter readings (Lasker, '54b).

Since the Photovolt colorimeter is of the balanced cell type, line voltage fluctuations should have little effect upon the galvanometer readings. Extensive tests confirmed this expectation. Settings made at 115 volts (normal line voltage)

did not change appreciably when the line voltage was increased to 130 volts, using a "Variac," nor did they decrease appreciably until line voltages dropped below 90 volts (fig. 1). Voltage fluctuations at the Fels Research Institute do not ordinarily exceed $\pm 2V$, as shown on a General Electric recording voltmeter; thus fluctuations in line voltage may be dismissed as a source of experimental error in the present investigation.

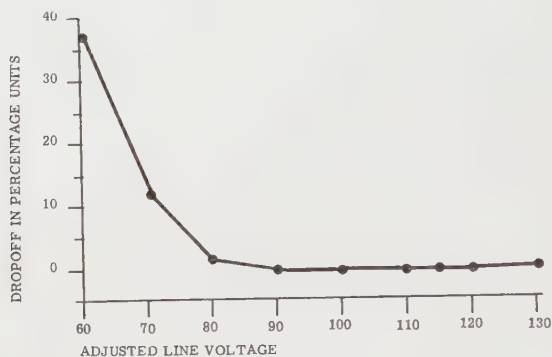


Fig. 1 Effect of line voltage fluctuations on colorimeter readings. If the galvanometer needle is correctly adjusted to 72% at 115 volts, variations in line voltage from 100 to 130 volts do not affect the readings. Since line voltage fluctuations in urban regions do not ordinarily exceed ± 2 volts, this source of measuring error may be ignored. Elsewhere a 6 volt storage battery should be used (cf. Lasker, '54a).

The colorimeter did prove subject to "drift," presumably due to expansion of the optical system, and warming-up of the tubes and other components. If switched on, and set to 72% reflectance (with the appropriate filter and test plate) decay immediately set in, reaching approximately 10 percentage points in the course of one hour (fig. 2). This downward drift was obviated in practice by three expedients, (1) affording a warming-up period of at least 30 minutes, (2) adjusting the galvanometer setting immediately before making a set of skin reflectance measurements and (3) checking the galvanometer setting immediately *after* making the measurements.

Immediate reproductibility of results appear to be high. Comparison of left and right areolar readings on 97 males

show a correlation of 0.93. Since the small non-systematic differences from side to side cannot be ruled out (and do in fact exist), the coefficient of immediate reproducibility is probably close to 1.0. Further, skin reflectance values of monozygotic twins match very closely, dizygotic twins are more different, and unrelated pairs most different. Differences in areolar reflectances for three pairs of monozygotic twins averaged 0.58 percentage points, as compared with 2.9 per-

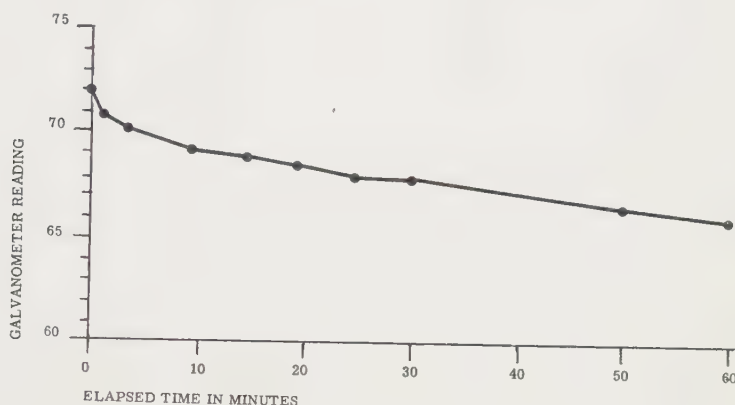


Fig. 2 Effect of "drift" on meter readings. If the galvanometer needle is correctly adjusted to read 72% reflectance one minute after switching on the colorimeter, drift over the succeeding 59 minutes drops the meter 10 percentage points. In practice, a warming-up period and adjustment of the galvanometer immediately before measuring are necessary (see text).

centage points for 4 sets of dizygotic twins, and 5.7 percentage points for 10 sets of unrelated children paired on the basis of age. The close similarity of the monozygotic twins measured at the same time helps to confirm the reliability of a series of measurements made under these conditions.

Long term reproducibility of results, however, is considerably lower and over a 6 month period no coefficient of reproducibility exceeds 0.60, whether for exposed or unexposed parts of the body (table 1). This lower long-term reproducibility is not due to the use of several observers, since all of the men were measured by one of us (S.M.G.) and the women

and children by another (S.S.). Nor is it entirely due to a shift from brighter to darker months of the year since the correlations take account of systematic shifts. Finally it cannot be attributed to varying amounts of dirt and grime, as reported for hand measurements by Lasker ('54b).

We have considerable evidence that some individuals are subject to relative long-term fluctuations in skin reflectance, but have not as yet been able to account for all of these fluctuations. In a small series of nulliparous females, followed over two menstrual cycles, there were definite individual trends in areolar reflectance, apparently unrelated to the menstrual cycle itself. In one set of female Negro triplets, all three

TABLE 1

Immediate and 6-month reproducibility of skin reflectance readings

GROUP	NO.	PART	REPRODUCIBILITY	MEAN	MEAN	CORRELATION
Adult males	97	Areola	Immediate	15.4 ¹	15.3 ²	0.93
Children 5-11	25	Forehead	6 month	24.7 ³	27.0 ⁴	0.56
Children 5-11	25	Left areola	6 month	22.6 ³	22.0 ⁴	0.58
Children 5-11	25	Inner arm	6 month	28.6 ³	27.8 ⁴	0.58

¹ Left areola.

² Right areola.

³ Summer months (May-October).

⁴ Winter months (November-April): note increased reflectance of forehead.

members of the set followed a parallel course in their 6-month changes, though the monozygotic pair remained closest throughout (fig. 3). In another set of male white triplets, the same phenomenon was observed, with one major change (scrotal reflectance) attributed to the latter maturation of triplet C. In other words, the failure of skin reflectance readings to match perfectly over 6 months or a year or more does not seem to be due to measuring error.

Finally, we should like to point out that the variable being reported here is skin reflectance at $\lambda 420$. While melanin is primarily involved, melanin is not the only pigment absorbing at this wavelength. (Just two years after the initiation of this study we discovered that pressure ischemia could yield

us measurements of reflectance primarily due to melanin, and without the interference of the blood pigment.) Further, while lower reflectance values indicate more melanin, and higher values indicate less, the relationship between percentage reflectance and melanin concentration is not linear, and melanin concentration cannot be estimated directly from percentage reflectance.

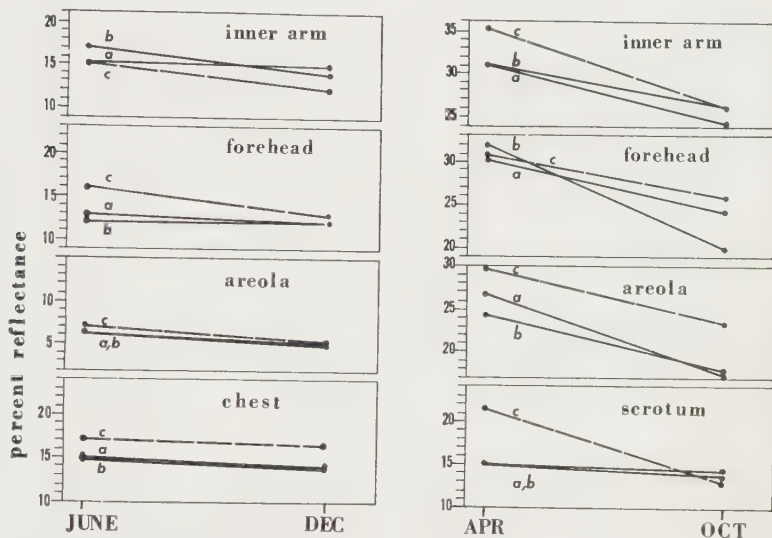


Fig. 3 Six-month skin reflectance trends in triplets. Left, a set of female Negro triplets. Right, a set of male white triplets. In each case (1) members of a set follow a parallel course, and (2) the monozygotic pair designated as "a" and "b" are more closely similar. These data help to indicate that apparent individual trends in skin reflectance are not primarily the result of measuring error.

FINDINGS

Starting first with the adult males, who constitute the single largest sex and maturity grouping, there is a distinct hierarchy of skin reflectance values and this is true at all age levels considered. As shown in table 2, the lightest areas reflecting over 30% of the incident light at λ 420, are those relatively unexposed to solar radiation—the upper inner arm and the chest. Next in order is the forehead, averaging about 20% reflectance in the blue end of the spectrum. Finally, come

two areas of “sexual skin” where melanin deposition is at least partially under steroid hormone control. The areola reflects 15% of the light on the average (as compared with 30% for the chest) while the scrotum averages a low 10% reflectance, with individual values as low as 4%. With slight exceptions and no major reversals, the sequence of reflectances followed by the mean values hold for individuals too; inner arm or chest, forehead, areola and scrotum. And, both for light skinned and dark skinned individuals the ratio of lightest to darkest areas approximates 3:1. The lightest skinned adult male in the present study had a chest reflectance of 42% and a scrotal reflectance of 14%.

The group under question definitely exhibits age trends in skin reflectance. Though the changes are not extreme, reaching 7 percentile points in only one area — the chest — the trend is for inner arm, chest and areola reflectances to increase with age ($\eta=0.36$ to 0.44), for forehead reflectances to decrease slightly (maximum change 4%, $\eta=0.33$) and for

TABLE 2
Changes in skin reflectance in men aged 20-60

AREA MEASURED	20-29				30-39			
	No.	Range	\bar{X}	S.D.	No.	Range	\bar{X}	S.D.
1. Lightest area	19	22-39	30.0	5.4	21	30-42	33.9	3.0
2. Inner arm	16	20-39	30.4	5.2	21	25-42	33.2	2.5
3. Chest	19	16-39	27.3	6.5	20	29-40	31.7	3.7
4. Forehead	19	14-35	22.3	4.3	21	13-27	21.9	3.6
5. Left areola	19	7-18	12.8	3.0	21	9-19	14.7	2.6
6. Right areola	19	7-18	12.6	3.0	20	11-20	15.0	2.0
7. Scrotum	19	7-14	10.3	2.0	20	10-14	11.5	1.4

AREA MEASURED	40-49				50-up				TOTAL GROUP				AGE CHANGE η
	No.	Range	\bar{X}	S.D.	No.	Range	\bar{X}	S.D.	No.	Range	\bar{X}	S.D.	
1. Lightest area	38	27-40	35.7	2.9	19	30-42	35.6	3.9	97	22-42	34.2	4.1	.51
2. Inner arm	36	20-40	33.8	3.6	19	27-39	33.3	3.3	93	20-42	33.0	3.7	.36
3. Chest	37	15-40	34.5	4.6	19	18-42	34.3	5.9	94	15-42	32.4	5.8	.36
4. Forehead	38	12-26	19.4	3.2	19	13-33	21.6	4.0	97	12-35	20.9	3.9	.33
5. Left areola	37	9-22	16.2	3.5	19	12-25	16.9	3.1	96	7-25	15.3	3.3	.42
6. Right areola	38	9-25	16.3	3.7	18	12-25	16.9	3.0	95	7-25	15.4	3.3	.44
7. Scrotum	35	4-14	10.4	2.2	18	7-18	11.0	2.7	92	4-18	10.7	2.2	.22

the scrotum to hold constant at about 10.5% reflectance ($r = 0.22$). The implications of these changes will be discussed in a later section.

Expectably, all of the skin areas measured in this reflectance study inter-correlate positively and for the most part significantly (table 3): men who are dark do tend to be dark all over. The highest correlation coefficients are obtained between inner upper arm and chest ($r = 0.70$) and between chest and areola ($r = 0.61$). The lowest correlation coefficient, 0.08 obtains between the forehead and the areola. Converting the r 's into Z transforms (see Fisher, '48), and averaging the Z 's for each area it becomes obvious that the inner arm and the

TABLE 3
Skin reflectance intercorrelations among 5 measured areas in the adult male

	INNER ARM	CHEST	FOREHEAD	AREOLA	SCROTUM	MEAN Z^1
1. Inner arm	...	0.70	0.27	0.51	0.38	0.53
2. Chest	0.08	0.62	0.25	0.48
3. Forehead	0.29	0.36	0.26
4. Areola	0.28	0.47
5. Scrotum	0.33

¹ Mean Z transform of r . (See Fisher, '48, table 2.)

chest have the greatest communality with the other areas, while the forehead has the least. Practically, this warrants at least two and preferably three reflectance measurements on each subject.

In contrast to the males, or specifically males between 20 and 29, infants are slightly lighter in inner arm and chest reflectances, and distinctly lighter by as much as 14 percentile points, in the sexual skin (table 4). The next group, immature boys and girls, tend to be darker in both arm and chest measurements, than either adults or infants, and approach the latter in forehead reflectance. Approaching maturity is indicated, reflectance-wise, by a marked sex difference in chest reflectance, while the sexually mature male and female are quite similar in skin reflectance, except in the pigmentation of

TABLE 4
Comparative skin reflectance values of children, adults and pregnant women

GROUP	AGE RANGE	NO.	INNER ARM		CHEST		FOREHEAD		LEFT AREOLA		SCROTUM	
			Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1. Infants ¹	0-4	30-33	29.9	3.9	29.2	3.7	27.6	3.7	24.2	4.1	15.8	4.2
2. Immature boys ²	4½-10	30-31	27.3	3.7	24.8	4.3	24.4	3.2	21.0	4.3	16.3	2.8
3. Immature girls ²	4½-10	14	27.0	3.7	26.4	4.8	25.7	4.4	23.3	3.4	...	...
4. Maturing boys ³	12½-16	17	27.8	5.2	24.9	5.7	22.9	5.1	18.8	4.6	16.2	4.1
5. Maturing girls ³	8½-15½	17	28.8	2.8	31.2	5.1	26.3	4.2	19.4	3.6	...	...
6. Mature nulliparae ⁴	14-25	23	29.4	3.6	32.5	5.4	23.7	5.0	14.8	3.5	...	...
7. Young adult males	20-29	16-19	30.4	5.2	27.3	6.5	22.3	4.2	12.8	3.0	10.3	2.0
8. Pregnant women ⁵	15-40	14	31.2	2.5	32.4	5.5	22.5	2.9	8.4	2.0	...	...

¹ Both sexes combined.

² Infantile areolae, no sexual hair.

³ Areolar enlargement and sexual hair, but epiphysial union incomplete.

⁴ Post-menarchial, epiphysial union complete.

⁵ Pooled data on 4th through 9th month of pregnancy.

the chest. Both have added very considerably to areolar pigmentation, and both show considerable evidence of tanning as indicated by the difference between forehead and inner arm reflectance readings.

The pregnant women constitute a group unto themselves. They closely resemble the mature nulliparae in inner arm reflectance (approximately 30%) in chest reflectance (about

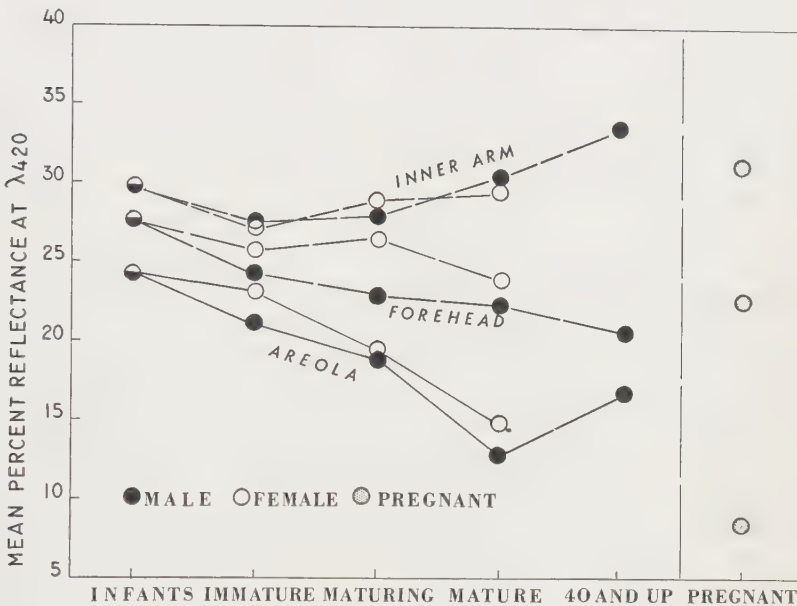


Fig. 4 Summarized age and sex differences in skin reflectance. Shown are (1) the decreasing reflectance of the "sexual" skin with maturity and especially with pregnancy, (2) the lightening of the unexposed skin, (3) increased areolar reflectance in the adult male and (4) the general tendency for the female to be slightly higher than the male in skin reflectance (see text).

32%) and forehead reflectance (about 23%), but differ from all other groups in areolar pigmentation. The mean areolar reflectance for these pregnant women is 8%, well below that for males, and the lowest values recorded, 3% and 4%, project below the limits of what would ordinarily be classed as white.

The general trends in skin reflectance by sex and maturity status, are shown in figure 4. Here several systematic changes

may be observed. First, the inner arm readings reach a minimum in immature children and rise consistently thereafter with little evidence for a consistent sex difference. The forehead, on the other hand, tends to become darker with advancing age, and here there is a suggestion that the women are, if anything, slightly lighter (three out of three pairings). Finally areolar reflectance decreases, through early maturity, decreasing even further in pregnancy. Here, again, with the exception of the latter state, the female tends toward higher reflectance readings. Until early adulthood the trend is toward intensification of pigmentary pattern; thereafter the distinctness of the pattern lessens except during pregnancy where it is at the greatest extreme.

DISCUSSION

The lightest area of skin, in this sample of American whites, reflects about 30% of the light in the blue end of the spectrum, and this "basal" value holds or rises slightly over 6 decades of life. The range of reflectance values for the lightest area is considerable however, being 25% in the darkest-skinned subject in the present study, and 45% in the lightest subject with blue eyes, red hair and almost albinic skin. Thus the basal skin color of so-called "whites" occupies half of the entire span of human reflectance values (1 to 50%) leaving the range 1 to 20% reflectance to the "blacks," "browns" and "yellows."

Within an individual, the mostly deeply pigmented areas are unquestionably those where melanin deposition is augmented by sex hormones, as in the areola in both sexes and the scrotum in the male. Expectably, in the young, the difference between those darkest areas and the lightest skin areas is relatively small. During sexual maturation, the reflectance range increases. It is slightly greater in the mature individual and reaches its maximum (20 or more percentage points) in the pregnant woman. The color pattern of a child is a dim copy of what it will be in the adult while the gravid female has the most vivid pigmentary pattern of all.

There is a definite trend toward heightening of skin reflectance on several parts of the body, from infancy through moderate age. In chest and inner arm readings immature boys and girls, and maturing boys, have distinctly lower readings than do adults. And, in the adult males, chest and inner arm readings increase somewhat over a four-decade period. There are several possible explanations for the lightening. The immature boys and girls may be most exposed to sunlight: certainly the differences in chest reflectance between maturing boys and girls represent differential exposure to light. Similarly the older men may go out in the sun less, or less frequently venture out shirtless. On the other hand the lower values in the young may be due to the presence of the pigment carotene, which has an absorption maximum at λ 480, close to the transmission maximum of the filter used, and which decreases markedly during maturation (Edwards and Duntley, '39).

The changes in areolar reflectance in the adult male, which are regular over the four decades investigated, may have an hormonal basis, but in the reverse direction of the changes during puberty. Certainly there is a decrease in urinary 17 ketosteroids over the age range 20 to 60 (Hamilton and Hamilton, '48; Pincus et al., '54) amounting to 5 mg/24 hours in the present group (unpublished data). However it is not safe to assume that two trends, merely linked in time, are necessarily causally connected and in the present group of adult males there is no evidence that—for constant age— areolar reflectance and 17 ketosteroid excretion are related.

Throughout, there is a suggestion of a sex difference in skin reflectance, with the female generally lighter than the male, except during the unique endocrine state that exists in pregnancy. In some areas the difference is clearly attributable to differential exposure to sunlight: compare the chest reflectance values of mature males and females. On the other hand, the forehead of immature girls tends to be slightly lighter (notwithstanding equal opportunities to tan), and the inner arm and areolae are lighter, even in the immature

state. Lasker ('54a), it may be noted, was able to find a statistically significant sex difference, for Paracho children, only at λ 650 and for the forehead. While Edwards and his associates confirmed the general impression that women are lighter and less ruddy (Edwards et al., '41; Edwards and Duntley, '49), documenting this difference by reflection colorimetry appears to be no easy task.

That hormones influence skin color is no new observation, though quantitative data are exceptionally rare. Various hormones promote melanin pigmentation by purely topical application alone (Davis et al., '45). Testosterone not only increases the basal pigmentation in castrates and eunuchs, but greatly enhances the ability of the eunuch to tan (Hamilton and Hubert, '38; see also Hamilton, '39). In recent years it has been shown that ACTH and Cortisone both affect skin pigmentation: Cortisone reverses the excessive pigmentation in Addisonism, while ACTH administration promotes increased production of melanin (Hall et al., '53).

However, the increases in areolar pigmentation observed in the present study need not be attributed to increased ACTH production, since the adreno-cortical stimulating hormone does not undergo an increase during puberty as do the gonadotrophins.³ Rather these pigmentary changes may be attributed to *both* gonadal hormones on the basis of experimental studies, and to so-called "androgens" of adrenal origin, which are the precursors of the bulk of the 17 ketosteroids excreted in the urine, and which Talbot prefers to call "dermatotrophic hormones" (cf. Talbot et al., '52). In the pregnancy changes, however, evidence points at the 20 ketosteroids, which are tremendously increased during this time, and which drop immediately upon parturition as does areolar pigmentation.

These studies, conducted at λ 420, obviously constitute only a beginning. Reflectance at other wavelengths must be deter-

³ This statement is based on the indirect evidence that the 11 oxysteroids do not increase after childhood, whereas the 17 ketosteroids do. If, however, there are several ACTH hormones as Talbot et al. ('52) suggest, or if ACTH is identical with "intermedin" (cf. Hall et al., '53; Lorincz, '54), then the role of "ACTH" in bringing about the pigmentary increases during puberty is even more obscure.

mined, and these reflectance values must be translated into pigment concentrations to be fully useful. Certainly, knowing how much of the pregnancy change is vascular and how much due to melanocyte stimulation, is a further step to take. Yet the present study does provide information on (1) how dark whites are, (2) how the pigmentary pattern changes with various endocrine states and (3) the extent to which the skin behaves as a unit, since this knowledge bears upon the number of reflectance readings that we have to take.

SUMMARY

1. The reflectance of the exposed, unexposed and "sexual" skin was measured at λ 420, using a Photovolt Reflection Colorimeter, in a series of 252 men, women and children.

2. Immediate reproducibility of results appear to be high ($r=0.9$), whereas the 6-month reproducibility coefficients did not exceed 0.6. The existence of verified individual trends, partially explained the failure of values to match perfectly half a year later.

3. On the average, the least-exposed skin reflected 30% of the light, with the range for this value approximately 25%–45%. Thus whites occupy in their basal skin reflectance, about half of the total human range.

4. In contrast to the least exposed skin, the most exposed skin of the forehead reflected close to 20% on the average, the areola closer to 15% in both sexes, and the scrotum close to 10%.

5. Age changes involved a gradual increase in the unexposed skin reflectance in the male, a darkening of the exposed (forehead) skin, and a lightening of the areola, the last presumably symptomatic of decreased hormonal secretion.

6. The most pronounced changes were observed in areola reflectance during pregnancy, with individual values dropping to 3.5% reflectance at mid-term.

7. On the basis of group intercorrelations, the use of three routine skin-reflectance measurements was recommended, (1)

a least exposed area, (2) a most exposed area and (3) one area (such as the areola) reflecting hormonal status.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Dr. Leland Clark, Jr. in testing the transmission of the blue (Corning) filter, and the work of Ruth Bean in scheduling the subjects and urine collections. At various times in the study we have had the help of Alan Charles Lapiner, and Mary M. Arginteanu. Dr. John I. Lacey was instrumental in simplifying our statistical analysis. Finally we should like to thank Dr. Paul Fejos and the Wenner-Gren Foundation for the initial loan of a Photovolt Colorimeter, and Dr. Aaron Bunsen Lerner for advice early in the study. We appreciate the assistance of Lois A. Conklin in the manuscript preparation.

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REVIEWS

THE ADAPTIVE CHIN. By E. Lloyd DuBrul and Harry Sicher.
(American Lecture Series No. 180.) 97 pp. Charles C Thomas,
Springfield, Ill. 1954. \$3.50.

A half century ago the tenor of evolutionary speculation was such that one could seriously state that a chin implied articulate speech and a higher evolutionary status for the being that was so blessed. Monkeys and apes and the lower forms of fossil men did not have such protuberances on the front of the base of the lower jaw. It was not many years, however, till comparative studies of primate mandibles showed differences in the shape and proportions of the mental region as well as differences in the angle and articulation; the relative position of the dental arch to the arch of the whole mandible was seen to change from form to form; phylogenetic reductions in tooth size were obvious too in such studies. Furthermore, human fetal mandibles were found to have separate mental ossicles and these called for explanation.

The harmonizing of all of these features posed a knotty problem of structural significance. Evolutionary transformation, however, served to explain the human chin; the different theories called for (1) shifts in the position of bone forming materials induced by fetalization, (2) formative influences arising from mechanical forces associated with tongue action and speech, (3) a reduction in the amount of supporting bone to harmonize with smaller teeth, and (4) the secondary mechanical influence of chewing-muscle forces upon phylogenetically altered patterns of bone structure. Little has been added to the picture during the past 20 years.

Now DuBrul and Sicher both review the historical developments in this field and present a critical evaluation of the data at hand. This is a handy package in itself. In addition they also carefully review a series of morphological changes that appear in the skulls and mandibles of a tree shrew, a lemur, two monkeys, a gibbon and a human. They maintain that, associated with the increasing tendency toward the erect posture in this series, there is (1) a forward migration of the foramen magnum on the cranial base and a shift in the plane of the foramen (relative to the normal body stance) from vertical to horizontal, (2) a movement forward of the posterior borders and angles of the jaw to avoid crowding of the neck viscera as the cranial

base shortens in harmony with the orthograde posture, and (3) an eversion of the whole lower border of the mandible from angle to angle, including the chin region. These changes are also associated with an anterior to posterior shift of cranial bulk, with a movement of the teeth from a more outward to a more lingual position relative to the bony arch of the mandible, and with slope changes in the axes of the cross sections of the bone as the mandible changes from a generally scoop-shaped to a plow-shaped structure. The lateral pterygoid muscles pull more transversely in the more advanced types of mandibles; the mental protuberance in the human, because of its anterior position, notably strengthens the bone relative to inward pulls of the lateral pterygoids.

The authors support their contention that the mandible adapts to the upright postural habit by further observations of a comparative sort. They compare the skull of an animal of normal quadrupedal habits with a semi-erect squatter-hopper type in each of two groups of mammals (Lagomorpha and the extinct South American Notoungulata). In each instance, as in the primate series, the mandibular base is more everted and the foramen magnum more horizontal in the semi-erect form than in the horizontal type.

The chin according to the view presented is an accessory adjustment in a wider phylogenetic adaptation to the upright posture involving both the mandible and the skull as a whole; brain enlargement, tooth reduction and changes in facial proportions have been concurrent trends which are to varying degrees correlated with the major postural adaptation. Like most concepts based upon the comparison of a handful of more or less selected type forms, these are not without an intrusive element of ingeniousness. The authors, nevertheless, do present a provocative idea which gets away from a myopic view of the chin as an entity in itself and treats of broader phylogenetic perspectives.

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GROWTH AT ADOLESCENCE. By J. M. Tanner. Pp. vii + 212.
Blackwell Scientific Publications, Oxford. Published simultaneously by Charles C Thomas and the Ryerson Press. 1955.

Until recently there was a total lack of books on human growth, and it was necessary to refer students to the clinically-oriented summaries in the larger pediatric textbooks, or to the longer review articles (like Stuart's) published in the medical journals. Now we have two editions of Watson and Lowrey's *Growth and Development of Children*,

Suarez' *Crecimiento*, and, most recently, Tanner's *Growth at Adolescence*.

This last-named volume, published in England by Blackwell and distributed in this country under the Thomas imprint, is neat, comprehensive and compact, presenting much more of growth than the fly-leaf promises. There is an excellent bibliography of 30 pages, valuable of itself, and a short supplementary chapter describing techniques in use at Harpenden Growth Studies. Throughout, all graphs whether original or borrowed, are drawn to uniform style and precisely labelled.

Tanner is most careful to distinguish between age-size trends ("distance curves") and age-increment trends ("velocity curves"). He carefully distinguishes between cross-sectional and longitudinal findings, proving that he practices what he preached in his paper "On the reporting of growth data." And if such precautions seem excessive, let us remember that no individual child grows like the trend-line on a "growth chart," and that the failure of children to match the behavioral sequence given by Gesell is due to the cross-sectional reporting of semi-longitudinal data.

This book has a physiological orientation with growth seen as an end-organ response to various trophic hormones. In consequence, rather more attention is devoted to endocrinology, and less to anthropometry. But the beloved problems of racial differences, secular and seasonal trends, and accelerated maturity are by no means ignored here. The emphasis is on why we grow, and less on the no-longer-new discovery that we do grow.

Because the physical changes in adolescence are imperfectly understood, there are many areas where the reviewer takes minor exception. For example it is by no means certain that male breast enlargement is caused by "oestrogens"; testosterone is quite likely the culprit instead. When the child or adolescent arrives at the adult serum cholesterol level is a moot point, as is the long-term stability of all serum lipid levels. The statement that the 17-ketosteroids and pigmentation are correlated (reference is given to unpublished data) may be questioned, since no such correlation appears in the reviewer's own (unpublished) data. Similarly, the lack of relationship between tooth emergence and steroid hormones contradicts growing experimental evidence, though it is in accord with scattered clinical reports. But in none of these examples is it possible to prove Tanner is wrong: rather there are several possible explanations, and his may be the right ones.

A noteworthy feature is the chapter entitled "the adolescent spurt in animals." It clearly shows that animals do have an adolescent spurt, though it is admittedly difficult to define "adolescence" for

the cow, the beagle and the marmoset. But the "spurt" appears to be more obvious in males, and especially (it would seem) where there is a marked sex difference in behavior. The extreme example given is that of the Fur Seals, where the harem-keeping male becomes so much larger than the female. But this is a most exceptional case: the bull seal lives off his fat for months while guarding his little family, and fighting off younger males and visiting anthropologists too.

In a short chapter on behavior at adolescence, Tanner dispels the notion of awkward adolescents, tottering under a load of unaccustomed steroids, and unable to navigate their new-found length and breadth. Here he is laying no pale ghost: this old doctrine is still taught as educational gospel! He searches for, and does not quite find, an adolescent "spurt" in intelligence. Here the rationale escapes the reviewer. It is most unlikely that the items to be passed on the Stanford-Binet or Wechsler-Bellevue would be affected by an increase in metabolic activity, nitrogen retention, or increased vascular flow.

This is a thoroughly professional work, calm and condensed, with no excess fat. It summarizes what is known, and attempts to explain without ever becoming wild. Interestingly, the bulk of the references are American, largely because long-term growth studies are older here, and more numerous than on the continent. Tanner has avoided complex mathematical treatments, including his own, thereby enhancing readability. Thus the problem areas become visible to the reader, at the same time he gains familiarity with growth at "adolescence" which, by the way, is not expressly defined.

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GEOCHRONOLOGY, WITH SPECIAL REFERENCE TO SOUTHWESTERN UNITED STATES. Edited by T. L. Smiley. Pp. 200, 38 figures. \$1.50. University of Arizona Bulletin XXVI-2, Physical Science Bulletin No. 2, Tucson. 1955.

In the last few years an interdepartmental geochronology program has been organized at the University of Arizona, the main (and in recent years the only) center of tree-ring studies in the Southwest. The group of papers by University of Arizona faculty members here published represents the essentials of a basic general course in geochronological methods, rather than a symposium. They include an up-to-date concise presentation of the theory and technique of several methods and approaches: astronomical aspects, particularly the unacceptability of the perturbation-insolation hypotheses to explain

Pleistocene glaciation¹ (by Edward F. Carpenter), radiochemical dating methods and, separately, radiocarbon techniques (by Edward N. Wise), geological stratigraphy (by John W. Anthony), paleontology (by John W. Lance), palynology (by Edwin B. Kurtz and Roger Y. Anderson), archeological stratigraphy (by Emil Haury), varves (by Terah L. Smiley), dendrochronology (by Doctor Smiley and Bryant Bannister), geological-climatic studies of the post-Pleistocene (by Ernst Antevs), and paleoclimatology in general (by James E. McDonald). In addition, a general introductory paper by Doctor Smiley on "The Geochronological Approach" is an important philosophical discussion of the measurement of time and the dating of past events, and of specimens representing or associated with such events, by various kinds of methods yielding dates for varying accuracy and significance.

The physical anthropologist should know of this bulletin as a convenient and compact reference on methods of dating archeological and geological materials. He will also do well to read, without awaiting provocation in connection with a specific problem, the introductory chapter by Smiley and at least leaf through other contributions, particularly those of Doctors Carpenter and Wise and Ernst Antevs, for general background for comprehension of the probable significance and limitations of dates published for archeological finds.

For both archeologists and physical anthropologists, a fundamental point of major importance — elementary but not always kept in mind — is that an "absolute" date, tree-ring, radiocarbon or other, applies directly only to the specimens as such and not necessarily to the event in the history of the world which the specimen is thought to represent. Dating the event is a matter of interpretation by the archeologist; the specialist who gives him a date on the charcoal or other specimen is responsible only for the date of that sample of material, not for its application.

To make clearer what is meant by this apparently minor and procedural distinction: if I send Ted Smiley a piece of wood, or a large collection of dendrochronological material, from an excavated ruin in the Southwest, and he finds a bark date of 1066 A.D., or even a group of dates clustering between 1060 and 1070 A.D., that does not necessarily mean that the pueblo from whose ruins the specimens came was built while Harold was marching back down from Stamford Bridge — as I might be tempted to assert when provided with a calendar date by a scientific method. The only definite *fact* is that the wood stopped growing — probably was cut — in 1066; the rest is

¹ Cf. W. L. Stokes, "Another Look at the Ice Age," *Science*, 122 (3174): 815-821, October 28, 1955.

interpretation, and should involve consideration of all possible ways the specimen could have reached the context in which it was found.² The same caution applies — in addition to questions of contamination and other special problems inherent in the technique and theory of the method — to radiocarbon dates.

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THE PILTDOWN FORGERY. By J. S. Weiner. Oxford University Press, London. 1955.

At this late date the essential outlines of the Piltdown forgery are known to scholars all over the world: how, thanks to the keen efforts of a younger generation of English scientists, it was found that there were discrepancies in the fluorine content between skull and mandible, that implements had been artificially stained, that the faunal remains had been introduced from more than one locality and that the teeth from an orang jaw had been deliberately ground down and painted. That the revelation of this unscrupulous deception has shaken lay confidence in anthropologists and their methods is unfortunate, but it is a tribute to the honesty of our English colleagues that in the name of reputable science they went relentlessly down the path to which the facts led them. In the end, science will benefit by such forthrightness and the formidable array of instruments now in the hands of the researcher will deter would-be pranksters from ever essaying such a venture again. What the public in some degree fails to realize is that we now have, not alone a much better idea of fossil man's anatomical makeup, but, in addition, the tests routinely carried out upon early sites are of a nature to prevent such falsification of the record. Piltdown had survived as a sacred object from the past, too sanctified in many eyes to be questioned. If there is a lesson in this story it lies here: new methods should always be used to check, wherever possible, the scientific conclusions of the past.

It would appear that another powerful reason for the widespread acceptance of the Piltdown cranium in the earlier years of this century lay in the intellectual atmosphere of the time. So strong were the prevailing modes of thought that even men who began by doubting ended by accepting the discovery. Previous finds of a few fragmentary Neanderthals and the Java skull cap had whetted curiosity but had

² For discussion of proper evaluation of dendrochronological results, see: T. L. Smiley, *A Summary of Tree-ring Dates from Some Southwestern Sites*, Laboratory of Tree-Ring Research Bulletin No. 5, University of Arizona, Tucson, 1951.

not really fixed our conceptions of fossil man. Weiner remarks in his preface that "for many people . . . Piltdown man represented Darwin's 'missing link'." Here in a nutshell is a good part of the story. Earlier discoveries had been made in the years of Darwinian controversy. They had been challenged, fought over and left doubtful. Even the Darwinians, such as Huxley, had handled them cautiously from fear of damaging the evolutionary cause.

By 1911, however, evolution was respectable in general intellectual circles; the dearth of transitional human material was keenly felt and, furthermore, there was a widespread impression, based on anatomical comparisons of man with the great apes, as to the probable appearance of our remote ancestors. Fossil man as conceived by Darwin and his followers was thought to possess huge, jutting canines. At the same time, man was supposed to have a very long history so far as the development of his brain was concerned. This notion was demanded partly by the infinitely slow, incremental nature of the Darwinian process and, secondly, by the initial disappointment which had struck the Darwinists when big-brained men had been discovered to be present in the later stages of the Ice Age. Paradoxically, the inadequate conception of the length of geological time had led to an eventual overestimation of human antiquity. The result was that a modern brain box attached to a primitive lower face was quite defensible. Moreover, it fitted so well into popular 'missing link' notions, particularly when comparisons were made with the living orang, that it bolstered the evolutionary viewpoint in no uncertain manner. Ironically enough, a complete fake was destined for many years to convince a doubting public of the reality of man's ascent from the anthropoids. Truth based upon falsehood lasted long enough to fill in the gap in evidence, before the discoveries of these last few decades began to make apparent on anatomical grounds alone, the anomalous position of Piltdown. No stranger story exists in the history of science.

Doctor Weiner has done an excellent, if hasty, job of presenting the full story of the hoax, including all the intriguing personalities who flit across the scene. I do not use the word "hasty" in a particularly critical sense. In order to reach as many of the general public as possible while their interest was still fresh, the book had to be written rapidly and as a consequence there are occasional errors of composition. For example, Straus's fine paper on Piltdown is mentioned with page and volume number, but no indication of the journal in which it appeared; nor does Straus's name appear in the index.

It is also a pity that as part of the story something more of the general intellectual climate of the period might not have been analyzed. This sort of effort takes time, however, and the time, unfortunately, was not available. What Doctor Weiner has given us is, actually, as

fascinating a real-life story of detection as has been published in many a day. If it teaches us the lesson that scientists are not immune from the common human disease of seeing what does not exist, it will have served its purpose. Our real danger lies in the fact that having solved this elderly hoax we may merely become more arrogantly confirmed in our own particular follies to the amused edification of some future generation. This reviewer, for one, finds no inclination to smile at our scientific forerunners. They were good men in a hazy and confused time and so are most modern scientists in their own fashion. It is more charitable to let *The Piltdown Forgery* stand for the human predicament in every generation; one can smile a little but not laugh—it is too close to home.

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THE MIDLAND DISCOVERY. By Fred Wendorf, Alex D. Krieger, and Claude C. Albritton, with a description of the skull by T. D. Stewart. Pp. viii + 139. \$3.50. University of Texas Press, Austin. 1955.

In spite of the long list of discoveries of human skeletal material of possible high antiquity in North America, each find seems destined to occupy a position in the penumbra of proof. In most cases the discovery came about in such a manner that the stratigraphic position of the bones was not determinable with certainty. Some probably ancient remains, such as Melbourne, Los Angeles Man, Tranquillity and the Natchez pelvis, have been examined with reference to their fluorine content, and in some instances these tests strongly support an opinion of their high antiquity. The craniometric examination of putatively ancient skeletal remains has on occasion led to the opinion by highly qualified workers that one or the other skull shows distinctive characters which are not typical of recent or late archaeological crania, and are probably to be interpreted as features characteristic of early American Indian types. In short, to date all of the earnest efforts have failed to find any acceptable evidence which would permit an unqualified opinion that certain human remains found in circumstances suggesting late Pleistocene or early post-Pleistocene age are in fact ancient and therefore exhibit characteristics of the North American Paleo-Indian.

Now, at long last, the chance discovery by an intelligent amateur, Keith Glasscock of Pampa, Texas, of human remains under conditions suggesting great age has been referred to competent students of archaeology and geology and the basic requisite for a sound conclusion, namely detailed study of the site before disturbance of the find, has been accomplished.

Location of the discovery is near Midland, in west central Texas. The actual site is named Scharbauer after the owner of the property. The original find consisted of human bone fragments lying on the surface in the bottom of a sand blowout in an area which yields fluted and unfluted Folsom projectile points. The bones, mostly of the skull, were heavily mineralized.

Albritton, the geologist, identifies two well known sand formations here, the upper (and later) one, Monahans; the inferior one, Judkins. The Judkins formation here is partly aeolian and partly lacustrine, and is divisible into three stratigraphic units, each separated by a disconformity. The lowest unit (No. 1), in which occurs *Equus*, *Camelops* and mammoth, as well as an abundance of shells of fresh-water snails and clams, marks the existence of a lake frequented by herbivorous animals. Unit 2 is more complicated geologically, but important in that campsite material occurs in it. The younger (Monahans) formation is divided into two stratigraphic units separated by a disconformity.

Extremely careful study of the stratigraphy convinced the authors that the human remains could not have washed down from a higher level or be the residual product of deflation, by wind erosion, of another layer. No signs of an intrusive pit could be detected. It is proposed "that the corpse was not buried but disintegrated on the surface of the gray sand when the sand was still accumulating and its surface lay at this level." The bones were, therefore, in place where found on and in Unit 2 of the Judkins formation.

Hearths, marked by concentrations of cobbles, occur in some numbers on top of the Judkins formation, from which level (surface of Unit 3) also come the Folsom projectile points. Minor evidence of man's presence in the form of flint chips and an *Equus* bone with cutting marks were found in the lowest (Unit 1) stratum of the Judkins—i.e. they are older than the human remains. The human bones are, however, pre-Folsom in point of time.

Chemical analyses of the fossil human and animal bones from the locality were made. Fluorine content as a test for relative age gave clear results. Thus modern bone (cottontail rabbit) from the site yielded .014–.027% fluorine, while *Equus* yielded .774–1.030% F, and the human bone .590–.860% F. (The lower sands gave .06 and .07% fluorine.) Determinations for nitrogen, carbonate and water give parallel results to fluorine. These are the same tests applied most recently, with such clear results, to the Piltdown remains. At Midland the chemical tests agree with the observations on stratigraphy. A sand sample saved by T. D. Stewart, while studying the bones, from the internal auditory aperture is like that of the Unit 2 layer of Judkins formation.

The human remains consist of a calvarium (plus teeth and some facial parts), two rib fragments and three metacarpals. They are described by T. D. Stewart, who presents excellent photographs and stereographic drawings of the calvarium. Stewart believes the skull to be female of about 30 years of age. He derives the following indices: cranial index (estimated), 68.8; upper height-length index (to bregma), 60.6; upper height-length index (to apex), 61.2; transverse frontoparietal index (estimated), 71.4; sagittal frontoparietal index, 160.7. Stewart sees general support for antiquity in the narrow and dolichocephalic skull. Direct comparison with older archaeological series is hampered by a dearth of measurements for females. A tentative comparison is made between the Midland skull and G. Neumann's Otamid variety, but Stewart frankly admits that much can be done in this direction with a fragmentary skull. But, at the same time he sees nothing in the skull to deny a claim of substantial antiquity.

The age of the Midland skull is not known. Three samples (mammoth tusk and fossil bone) from the top of Unit 1 of the Judkins formation gave an age determination by radiocarbon method of $8,670 \pm 600$ years. Fossil bone from the gray sand (Unit 2, Judkins formation) which produced the human remains gave a radiocarbon age of $7,100 \pm 1,000$ years. The authors (p. 100) incline to consider these dates as incorrect partly on account of the nature of the samples, their inconsistency with the presumptive age of the Pleistocene fossils in the lower Judkins sands, and because the Folsom culture occurring on top of the Judkins formation has been radiocarbon dated at Lubbock, Texas, at $9,883 \pm 175$ years. The reviewer agrees that these considerations are sufficient to warrant holding the Midland radiocarbon dates as "ceiling dates" which may be older but cannot be younger.

The authors have proceeded in their field study, laboratory analyses and writing with deliberation and caution. They have not stretched any evidence, but have stuck to facts and what conclusions these will support. They have dealt as adequately as possible with difficult problems of occurrence, geological interpretation and dating, and the reviewer is in agreement with their findings. This report is definitely the best of its kind yet produced, and the Midland maid, for all her incompleteness, will almost certainly be accepted as the oldest authenticated American human fossil.

Not the least significance of the Midland report is the existence now of a model which may serve to stimulate other collectors and professionals to do full-scale multi-discipline studies at the sites of finds which will surely be made in future.

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RADIOLOGICAL STUDIES OF VARIATION IN THE SEGMENTATION AND OSSIFICATION OF THE DIGITS OF THE HUMAN FOOT

VARIATION IN LENGTH OF THE DIGIT SEGMENTS CORRELATED
WITH DIFFERENCE OF SEGMENTATION AND
OSSIFICATION OF THE TOES

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TWO FIGURES

INTRODUCTION

The investigation reported here is concerned with measurement of variations in the length of the segments of the digits of the foot in relation to the different types of ossification and segmentation of the phalanges of the 2nd–5th toes. The results are considered in connection with their bearing on an hypothesis of the morphogenesis of the different types of skeletal development which was postulated in a previous study (Venning, '55). This hypothesis supposes that the discontinuous series of 4 skeletal forms observed to occur among the 2nd–5th toes are expressions of different values of a continuous morphogenetic variable, namely digit blastema length. Thus it is supposed that this continuous variable is subdivided by three critical threshold values into 4 ranges of values, each of which gives rise in the course of development to one of the 4 skeletal types that occur on these toes.

LITERATURE

In a previous paper (Venning, '55) the different types of ossification and segmentation of the phalanges of the 2nd–5th

toes observed among radiographs of the feet of samples of children and adults were described. The types distinguished were as follows:

1. Toes with two phalanges in which the proximal ossified from two centers (a primary center and a proximal epiphysis) and the terminal ossified from a single center.

2. Toes with two phalanges each of which ossified from two centers.

3. Toes with three phalanges in which the terminal and proximal each ossified from two centers, but the middle phalanx ossified from single center with no epiphysis, or with only partial epiphyseal development (pseudo-epiphyses).

4. Toes with three phalanges, each of which ossified from two centers.

These types may be arranged to form a discontinuous series in which each successive step is distinguished by the increment of one center of ossification; one critical step ($2 \rightarrow 3$) is also accompanied by the formation of an additional joint. It was found that, when more than one type was present in the same foot, toes with the smaller number of centers or joints are always lateral to those with the greater number. An analysis of the frequency distributions of the different types with respect to sex, right and left foot, and toes, together with their relative positional order in the foot, showed that there was an association between relatively short digits and those types of ossification with the fewer ossification centers and phalanges. This finding prompted the postulation of the hypothesis quoted above, although it was pointed out that an association between digit length and skeletal form does not necessarily imply a causal connection between the two.

The results of other investigations into the occurrence of these differences in ossification, e.g. frequency differences in European and Japanese (Hasebe, '12); frequencies of occurrence of toes with two and three cartilaginous phalanges in fetuses (Trolle, '48), and sib correlations with respect to the number of phalanges on the 5th toe (Venning, '54), were

discussed in relation to this hypothesis and were considered to be consistent with it.

Pfitzner (1893) published data on variations in the lengths of the digits and digit segments of adult post-mortem feet in relation to the number of phalanges in the 5th toe. He reported the following results:

1. The mean length of the terminal phalanx of 5th toes with two phalanges is greater than the mean combined lengths of the terminal and middle phalanges of 5th toes with three phalanges, neglecting joint spaces.

2. The mean length of the terminal phalanx of each of the other toes, including the 1st, is greater when the 5th toe has two phalanges than when it has three.

3. The mean lengths of the metatarsals, proximal phalanges and middle phalanges on each digit is less when the 5th toe has two than when it has three phalanges. The difference was greatest in the case of the middle phalanges and least in the case of the metatarsals.

4. The mean of the sum of the lengths of the segments of each digit is less when the 5th toe has two than when it has three phalanges.

The differences on which these results are based are in some cases small, and in no case is it possible to apply a statistical test of significance.

MATERIAL AND METHODS

The measurements of the lengths of the digit segments were made on radiographs of the feet of samples of children and young adults of both sexes. The male samples consisted of 149 children (88, 7 years old; 61, 8 years old) and 154 adults. The female samples consisted of 173 children (80, 5 years old; 93, 6 years old) and 83 adults.

All the radiographs were dorsi-plantar projections of the feet taken under the following standard conditions; the subjects were seated with knees together and slightly flexed; the feet were placed in contact side by side resting on the

film; the x-ray tube was 100.0 cm from the film centered between the heads of the two 1st metatarsals.

Measurements were made with a transparent perspex ruler placed in contact with the film, which rested on a horizontal glass table illuminated from below. The greatest proximo-distal dimension of the image of each segment was measured to the nearest 0.5 mm. A preliminary trial failed to reveal any significant differences between right and left sides with respect to a number of selected measurements. All the measurements given here were made on left feet.

Each of the digits measured was classified according to whether the middle phalanx possessed or lacked an epiphysis, or had two or three phalanges, and the mean lengths of each segment were compared with respect to these categories. Values of $P < 0.05$ were taken as showing significant differences.

It will be noticed that this classification of the digits does not distinguish between the toes with two phalanges the terminal of which ossify from one or two centers. The former of these two types is too rare for this distinction to be useful.

Errors. Quantitative estimation of the different errors have not been attempted, but the principle sources of error are described below.

(a) *Technique.* As far as positioning of the feet and x-ray tube, and making the measurements on the films are concerned, a previous investigation with respect to other measurements of the foot obtained in a similar way from radiographs taken in standard positions (Venning and Hardy, '51) gives grounds for believing that estimations of length using the methods described above are sufficiently accurate to discriminate differences of 0.5 mm in most cases.

(b) *Foreshortening.* Variations in flexion and consequent foreshortening of the images became increasingly great the more distal the segment. In the case of the terminal phalanges of 2nd-5th toes these errors are manifestly so large that these segments were not measured. In the case of the middle phalanges these errors are not so great, and there

is no reason to suppose that they preferentially select either middle phalanges with or without epiphyses. Fortunately also the differences in the lengths of these phalanges with respect to two forms of ossification are particularly large. Variations in flexion probably do not significantly affect the measurements of the proximal phalanges or metatarsals, but, in the case of the latter segments on the 1st-4th digits there is often some uncertainty in identifying the proximal limit of the image.

(c) *Age*. Differences in age within the samples of children provide another source of unwanted variation in length. These samples were for this reason restricted in each sex to two consecutive yearly age groups. The still more restricted choice of a single yearly age group would not provide large enough samples. The choice was in any case limited to male children from 7 to 10 years old inclusive and female children from 5 to 8 years old inclusive, since only at these ages can the different forms of ossification be distinguished with certainty in nearly every child. The two youngest yearly ages of these ranges in each sex were selected in order to reduce as far as possible any accumulations of error due to differences in rates of growth. Insofar as variations in length due to differences in age are independent of the form of ossification they merely serve to obscure length differences with respect to the form of ossification. It might be supposed however that the rate of growth of segments which lack epiphyses will be less than the ones which possess epiphyses. If this were the case, errors due to age variation would be biased with respect to the form of ossification as far as the lengths of middle phalanges were concerned. Any length differences of these segments with respect to the form of ossification would then contain a component due to this error. The present material does not permit any direct measurements of growth rate by which the magnitude of this effect could be estimated. It was however possible to compare the ratios of the mean lengths of the middle phalanges with and without epiphyses at the two yearly ages

represented in the samples of each sex. It was found that the magnitude of the ratios showed changes with respect to age of opposite sign in the two sexes. Unless this finding is assumed to represent a real sex difference, which seems unlikely, it may be interpreted as showing that there is no great systematic difference between the rates of growth of middle phalanges with and without epiphyses over the period

TABLE 1

Correlations between the lengths of pairs of digit segments in adult females
(i) Intra-digit correlations between the lengths of pairs of abutting segments

DIGITS	SEGMENTS	NO. OF PAIRS	CORRELATION COEFFICIENT (r)	P
1st	Ter Ph: Prox Ph.	83	+ 0.542	< 0.001
	Prox Ph: Met.	83	+ 0.690	< 0.001
2nd	Mid Ph: Prox Ph.	82	+ 0.364	< 0.001
	Prox Ph: Met.	83	+ 0.396	< 0.001
3rd	Mid Ph: Prox Ph.	81	+ 0.311	< 0.010
	Prox Ph: Met.	83	+ 0.436	< 0.001
4th	Mid Ph: Prox Ph.	79	+ 0.222	< 0.050
	Prox Ph: Met.	83	+ 0.427	< 0.001
5th	Mid Ph: Prox Ph.	48	+ 0.306	< 0.050
	Prox Ph: Met.	83	+ 0.462	< 0.001

(ii) Inter-digit correlations between the lengths of adjacent pairs of corresponding segments

SEGMENTS	DIGITS	NO. OF PAIRS	CORRELATION COEFFICIENT (r)	P
Mid-Phals.	2nd: 3rd	81	+ 0.804	< 0.001
	3rd: 4th	79	+ 0.757	< 0.001
	4th: 5th	47	+ 0.557	< 0.001
Prox. Phals.	1st: 2nd	83	+ 0.528	< 0.001
	2nd: 3rd	83	+ 0.789	< 0.001
	3rd: 4th	83	+ 0.898	< 0.001
	4th: 5th	83	+ 0.751	< 0.001
Metatarsals	1st: 2nd	83	+ 0.728	< 0.001
	2nd: 3rd	83	+ 0.902	< 0.001
	3rd: 4th	83	+ 0.910	< 0.001
	4th: 5th	83	+ 0.786	< 0.001

of one year which separates the mean ages of the two samples in each sex.

(d) *Intersegment correlations.* In assessing the significance of any measurement the highly significant intra-foot correlations with respect to the lengths of the digit segments must be taken into consideration (table 1). These correlations ensure that the sampling errors of the different measurements are not independent.

RESULTS

(1) *Length of the segments of the 1st digit
with respect to the forms of ossification
of the 2nd and 5th toes of the
same foot*

The mean lengths of each segment of the 1st digit were compared (a) with respect to the presence or absence of epiphyses of the middle phalanges of 2nd toes in the male and female samples of children; and (b) with respect to the presence of two or three phalanges in the 5th toes in the male and female samples of children and adults.

None of the differences were significant, nor were they consistently in the same direction. This result fails to confirm Pfitzner's (1893) finding that the mean lengths of the terminal phalanges of each of the toes, including the 1st toe, is greater among feet with two phalanges on the 5th toe.

(2) *Lengths of the middle phalanges*

(a) *Length gradient among middle phalanges analyzed with respect to the presence or absence of epiphyses.* Table 2 shows the mean lengths of the middle phalanges, analyzed with respect to the different toes and to the presence or absence of an epiphysis, listed in order of magnitude.

The mean lengths of both types of middle phalanges shows a decreasing medio-lateral gradient among the toes in both sexes. This gradient corresponds to the medio-lateral length gradient of the whole digits (Pfitzner, 1893). The two types

TABLE 2

The mean lengths of middle phalanges, analyzed with respect to toe and presence or absence of epiphyses, arranged in order of magnitude

	TOE	MALES				FEMALES			
		Lengths (mm) of middle phalanges			Differences between successive pairs of means	Lengths (mm) of middle phalanges			Differences between successive pairs of means
		N	Mean	S.D.		N	Mean	S.D.	
Without epiphyses	5th	87	4.78	0.67	10.40 < 0.001	102	4.50	0.65	10.03 < 0.001
	4th	117	5.99	0.92	3.56 < 0.001	153	5.54	0.90	5.01 < 0.001
	3rd	66	6.47	0.80	4.69 < 0.001	99	6.11	0.85	4.76 < 0.001
	2nd	24	7.40	0.92	3.32 < 0.010	38	6.88	0.84	2.80 < 0.010
With epiphyses	4th	30	8.35	1.13	3.61 < 0.001	15	7.60	0.86	1.25 > 0.100
	3rd	82	9.25	1.18	5.06 < 0.001	73	8.05	1.33	3.75 < 0.001
	2nd	124	10.15	1.29		135	8.67	1.02	

of middle phalanges together form a single length gradient in each sex in which the smallest mean length of phalanges with epiphyses (those on the 4th toe) is significantly greater than the largest mean length of phalanges without epiphyses (those on the 2nd toe). This result, though it might arise from a variety of circumstances, is a necessary consequence of the hypothesis of morphogenesis under consideration if the continuous variable postulated is in this instance taken to be the length of the middle phalanx instead of digit length. The hypothesis would then state that at some stage of differentiation all middle phalanges longer than a threshold value will develop epiphyses, while all those shorter than this value will not.

(b) *Length distribution of the middle phalanges on 5th toe.* By an extension of the above argument it may be supposed that the absence of the middle phalanx, i.e. the segmentation of a toe into two instead of three phalanges, may be regarded as the end product of a continuous reduction in the length of this phalanx. In morphogenetic terms this may be expressed by supposing that when the available tissue for the formation of a middle phalanx is less than a threshold length no middle phalanx is differentiated. If this were so then the length distribution of middle phalanges of the 5th toe (which frequently has only two phalanges) would tend to be skew, with the shorter lengths less dispersed relative to the mode than the longer. This effect should be more pronounced among females than males since 5th toes with two phalanges are commoner in females. Consequently it may be supposed that mean lengths of the middle phalanges of this toe is closer to the threshold value in females than in males. Figure 1 shows the distributions of the lengths of middle phalanges of the 5th toe in samples of adult males and females. These distributions show to some extent the effects predicted.

(c) *Inter-toe correlations with respect to length of middle phalanges.* The original formulation of the hypothesis made the generalized proposition that the series of skeletal

types were produced by differences of *digit length* during differentiation. The analysis of the lengths of middle phalanges so far presented has led to the introduction of a more specific proposition not necessarily implied by the original formulation but consistent with it; that both the two types of ossification of the middle phalanges and the absence of a middle phalanx result from variations in the *length of the middle phalanx or presumptive middle phalanx* at some stage in ontogeny. Thus the segmentation of a toe into two pha-

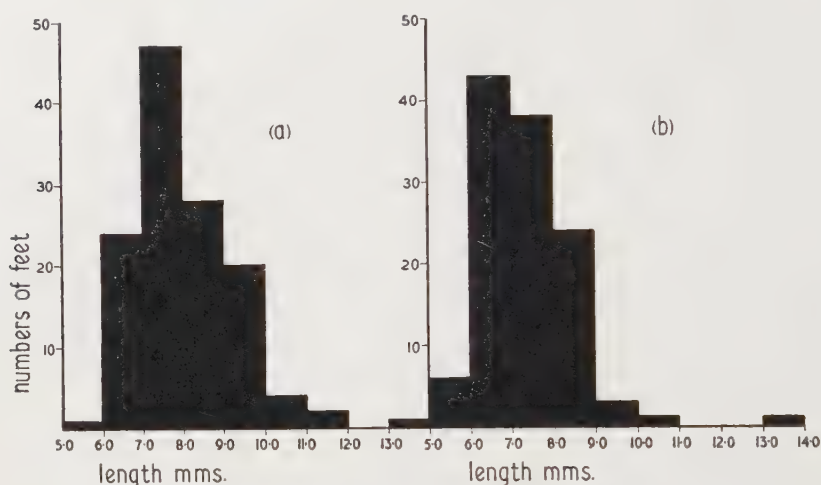


Fig. 1 Distribution of lengths of middle phalanges of 5th toes among (a) 127 adult males, and (b) 116 adult females.

langes is assumed to be a special case of extreme shortness of this phalanx.

It can be predicted from this assumption that inter-digit correlations with respect to the lengths of middle phalanges (table 1, ii) should result in the middle phalanges of the 2nd, 3rd, and 4th toes being shorter when the 5th toe has two, than when it has three phalanges.

Some results consistent with this prediction have already been obtained. Thus it has been shown (Venning, '55) that the occurrences of middle phalanges lacking epiphyses on

the 3rd, 2nd and 4th toes are significantly correlated with the occurrence of two phalanges in the 5th toe of the same foot. This correlation would be sufficient to account for Pfitzner's (1893) observation that in adults the middle phalanges of the 2nd, 3rd and 4th toes are shorter when the 5th toe

TABLE 3

Comparisons of the lengths of the middle phalanges of each toe with respect to differences in the type of ossification on the middle phalanges of other toes of the same foot: child samples

(i)

		LENGTHS (MM) OF MIDDLE PHALANGES WITH NO EPIPHYSES, WHEN MIDDLE PHALANGES OF MORE MEDIAL TOES HAVE						DIFFERENCE BETWEEN MEANS OF (a) AND (b)	
		(a) No epiphyses			(b) Epiphyses				
		N	Mean	S.D.	N	Mean	S.D.	t	P
Males	3rd toes	24	6.188	1.007	42	6.643	0.617	2.28	< 0.05
	4th toes	65	5.577	0.782	52	6.500	0.816	6.22	< 0.001
	5th toes	61	4.557	0.535	26	5.308	0.848	4.99	< 0.001
Females	3rd toes	37	5.676	0.965	62	6.347	0.738	3.89	< 0.001
	4th toes	95	5.179	0.867	58	6.138	0.654	7.25	< 0.001
	5th toes	88	4.432	0.723	14	4.964	0.572	8.29	< 0.001

(ii)

		LENGTHS (MM) OF MIDDLE PHALANGES WITH EPIPHYSES WHEN MIDDLE PHALANGES OF MORE LATERAL TOES HAVE						DIFFERENCE BETWEEN MEANS OF (a) AND (b)	
		(a) No epiphyses			(b) Epiphyses				
		N	Mean	S.D.	N	Mean	S.D.	t	P
Males	2nd toes	42	9.357	1.181	82	10.561	1.171	5.40	< 0.001
	3rd toes	52	8.788	1.074	30	10.050	1.341	4.67	< 0.001
Females	2nd toes	62	8.315	0.808	73	8.973	1.122	3.85	< 0.001
	3rd toes	58	7.922	0.862	15	8.500	1.310	2.06	0.05

has two than when it has three phalanges, since there are large length differences between the toe types (table 2), and his measurements did not distinguish between them.

Thus Pfitzner's results depend primarily on frequency correlations between the skeletal types and do not provide direct evidence of the length correlations predicted above.

In an attempt to obtain such evidence the inter-toe correlations with respect to middle phalanx length have been analyzed for each type of ossification separately. Tables 3 (i) and (ii) give the results of this analysis. The comparisons

TABLE 4

Comparison of the mean lengths of middle phalanges of the 2nd-4th toes with respect to the number of phalanges on the 5th toes: child samples

(i)

		LENGTHS (MM) OF MIDDLE PHALANGES OF 2ND-4TH TOES WITH NO EPIPHYSES WHEN THE 5TH TOE OF THE SAME FOOT HAS						DIFFERENCE BETWEEN MEANS OF (a) AND (b)	
		(a) Two phalanges			(b) Three phalanges				
		N	Mean	S.D.	N	Mean	S.D.	t	P
Males	2nd toe	16	7.062	0.795	8	8.062	0.906	2.77	< 0.02
	3rd toe	41	6.232	0.775	25	6.880	0.634	3.52	< 0.001
	4th toe	56	5.518	0.841	61	6.418	0.769	6.06	< 0.001
Females	2nd toe	30	6.600	0.607	7	7.929	1.095	4.43	< 0.001
	3rd toe	60	5.883	1.034	39	6.449	0.800	2.90	< 0.010
	4th toe	65	5.062	0.779	88	5.903	0.814	6.43	< 0.001

(ii)

		LENGTHS (MM) OF MIDDLE PHALANGES OF 2ND-4TH TOES WITH EPIPHYSES WHEN THE 5TH TOE OF THE SAME FOOT HAS						DIFFERENCE BETWEEN MEANS OF (a) AND (b)	
		(a) Two phalanges			(b) Three phalanges				
		N	Mean	S.D.	N	Mean	S.D.	t	P
Males	2nd toe	45	10.011	1.413	79	10.234	1.349	0.87	> 0.10
	3rd toe	20	9.050	1.513	62	9.315	1.259	0.78	> 0.10
	4th toe	(only 4 examples)						...	...
Females	2nd toe	41	8.610	0.931	95	8.689	1.165	0.38	> 0.10
	3rd toe	10	8.000	1.054	63	8.048	1.649	0.131	> 0.10
	4th toe	(only 1 example)						...	...

show that the mean length of middle phalanges of each type on any particular toe varies significantly with respect to the type (and therefore the length) of the middle phalanges of the other more medial and more lateral toes. The differences are all in the same direction, i.e. shorter when the

middle phalanges of the other toes lack epiphyses and longer when they have epiphyses.

If, therefore, toes with two phalanges represent morphogenetically toes with extremely short middle phalanges then similar relationships should be found between the lengths of middle phalanges of each type of ossification on the 2nd-4th toes, and the number of phalanges on the 5th toes. Tables 4 (i) and (ii) show the results of these measurements. It will be seen that in the case of middle phalanges which lack epiphyses the predicted differences are found and are significant (table 4, i). In the case of middle phalanges with epiphyses the differences all have the predicted sign, but they are not significant (table 4, ii).

It may be concluded that in general these results confirm the prediction that, from the point of view of inter-toe correlations between the lengths of middle phalanges, 5th toes with no middle phalanges may be regarded as representing toes with extremely short middle phalanges.

3. Lengths of the proximal phalanges

In tables 5 (i) and (ii) the mean lengths of the proximal phalanges on each toe are compared with respect to the type of ossification of the middle phalanx, or the number of phalanges, on the same toe.

The results of these comparisons show that in the 2nd, 3rd and 4th toes of females the mean lengths of the proximal phalanges are significantly shorter when the middle phalanx lacks an epiphysis than when it possesses one. In males the differences in length are all in the same direction but are significant only in the case of the 4th toe. On the 5th toe no significant or consistent differences in the length of the proximal phalanx with respect to the number of phalanges were found.

These results, though inconclusive, indicate that the length of proximal phalanges on the 2nd-4th toes are probably related to the type of ossification of the middle phalanges.

If this is so then the middle phalanges are not the only segments of the digits whose lengths are related to the skeletal differences. The interpretation of these results is complicated by differences which occur in the form of the epiphyses

TABLE 5

Comparisons of the lengths of proximal phalanges on each toe with respect to (i) the type of ossification on the middle phalanx of the same toe, and (ii) the number of phalanges in the same toe

(i)

		LENGTHS (MM) OF PROXIMAL PHALANGES WHEN THE MIDDLE PHALANX OF THE SAME TOE HAS						DIFFERENCE BETWEEN MEANS OF (a) AND (b)	
		(a) No epiphyses			(b) An epiphysis				
		N	Mean	S.D.	N	Mean	S.D.	t	P
Male children	2nd toe	25	20.48	1.93	124	20.88	1.42	1.21	> 0.20
	3rd toe	67	18.55	1.82	82	18.96	1.21	1.63	0.10*
	4th toe	119	17.36	1.43	30	18.02	1.06	2.37	0.02
Female children	2nd toe	38	18.08	1.45	135	18.62	1.36	2.13	< 0.05
	3rd toe	100	16.40	1.22	73	17.07	1.42	3.33	0.001
	4th toe	158	15.53	1.09	15	16.77	1.59	4.03	< 0.001

* Mean of (b) significantly greater than that of (a) in 8 year sample, but not in 7 year sample.

(ii)

		LENGTHS (MM) OF PROXIMAL PHALANGES OF 5TH TOES WHEN THIS TOE HAS						DIFFERENCES BETWEEN MEANS OF (a) AND (b)	
		(a) Two phalanges			(b) Three phalanges				
		N	Mean	S.D.	N	Mean	S.D.	t	P
Males	Children	62	16.13	1.27	87	15.93	1.28	0.95	> 0.30
	Adults	59	24.12	1.77	95	24.23	1.95	0.34	> 0.70
Females	Children	71	14.44	0.87	102	15.32	1.15	0.74	> 0.40
	Adults	35	22.14	1.69	48	22.12	1.29	0.06	> 0.90

of the proximal phalanges, which are correlated both with the length of these phalanges and with the type of ossification of the middle phalanx. The frequency distribution of these epiphyseal differences among the toes is, however, quite different to that of the skeletal types with which this study is

concerned, in that they most often occur in the 3rd toe, next in the 4th toe and least of all in the 5th. These epiphyseal differences among proximal phalanges will be described and analyzed in another communication.

(4) *Length of metatarsals*

The mean lengths of the metatarsals of each of the 2nd, 3rd and 4th digits were compared with respect to the presence or absence of epiphyses of the middle phalanges of the same digit in the male and female samples of children. The mean lengths of the metatarsals of the 5th digit were compared with respect to the presence of two or three phalanges in this digit and the male and female samples of children and adults.

None of the differences were significant, nor were they consistently in the same direction. Contrary to Pfitzner's (1893) finding, therefore, the metatarsals do not, in the present material, vary in length with respect to the skeletal differences in the toes.

DISCUSSION

The results obtained from the comparisons of the measurements of the separate segments of particular digits with respect to the skeletal types distinguished, confirm and explain the more general relationship previously observed between the frequency distributions of the skeletal types and digit length.

Pfitzner's (1893) measurements indicated that, except in the case of the terminal phalanges, there are positive correlations, neglecting the different forms of ossification, between digit length and the lengths of the component segments. The decreasing length of the digits medio-laterally across the foot is accompanied by a reduction in the length of each of the segments, with the possible exception of the terminal phalanx. The middle phalanges show the greatest decrease both proportionally and absolutely, and become reduced in the more lateral toes to the shortest bones of the entire appendicular skeleton

of the body. The accompanying length decrements are less in the proximal phalanges, and least in the metatarsals.

The present study has indicated that the general relationships between digit lengths and the three skeletal types distinguished are probably mediated by the correlation between each of these variables and middle phalanx length. The morphogenetic connection between digit length and skeletal type may therefore be postulated as follows: the shorter the digit blastema the shorter the middle phalanx; when the digit blastema is less than some critical length the resulting middle phalanx does not attain to the threshold length required for the development of a separate epiphyseal ossification; if the digit blastema is still shorter the presumptive middle phalanx may not attain to the threshold length required for the development of a joint between this segment and the more distal segment.

There remains a further skeletal difference not distinguished in this study, namely the development of either one or two ossification centers in the terminal phalanx of those with two phalanges. If this difference, which in other respects appears to be part of the series of skeletal differences, is to be included in the morphogenetic explanation, then it may be supposed that a progressive diminution of digit length finally reduces the absolute length of the terminal phalanx to less than the critical value necessary for the development of two centers of ossification.

The morphogenetic hypothesis that has been proposed here is in opposition to Pfitzner's conclusion (1890, 1896) that toes with two phalanges are formed during ontogeny from three phalanges by fusion between the terminal and middle segments. This view has been held by all subsequent commentators. In support of this theory Pfitzner (1890) presented some indirect embryological evidence for what he interpreted as partial fusion between these phalanges. This evidence can, however, equally well be interpreted in terms of partial or abortive segmentation.

It remains to consider whether studies of the morphogenesis of the skeleton provide any evidence in support of the hypothesis proposed.

Tschumi ('53) compares the experimental reduction of the limb-bud blastema of *Xenopus* by the local application of mitotic inhibitors, with the phylogenetic reduction of some of the digits seen in many animals. He concludes that both may be interpreted in terms of chemical competition between digit-primordia. He points out that the phylogenetic strengthening of a particular digit is regularly accompanied by the reduction of others.

To apply this conclusion to the skeletal differences in the digits of the human foot it appears necessary to suppose that the relatively great development of the 1st digit gives rise to the reduction of the more lateral toes. Such a description is however inadequate, since, at the time of segmentation it is probable that the 1st digit is the shortest digit of the foot; its relatively great size only being achieved later in ontogeny (Schultz, '24; Straus, '27). For this reason it has been suggested (Venning, '55) that the presence of two phalanges in the 1st toe arises from the same circumstance that produces two phalanges in the 5th and other toes — namely digit shortness at the time of segmentation.

The observations of Harris ('33) on long bones, and of Haines ('33, '42) on epiphyses, suggest that a minimum volume of cartilage is probably one of the conditions necessary for the onset of ossification. Grüneberg ('51, '53) presents evidence from mice that absence of a skeletal part, or tooth, results when the presumptive tissue condensation is less than a threshold size. In less extreme cases of reduced size he reported that there appeared to be a delay in the onset of chondrification and ossification of the part.

The critical dimensions relating tissue size to differentiation are presumably volume and surface area. Since these dimensions must be closely correlated with length in the case of the digits, the above observations are consistent with the conclusions that middle phalanges are absent or lack epiphyses

when they are less than some threshold length at the appropriate stage of development.

Fell and Canti ('34) reported observations on the chondrification and segmentation of limb-bud explants from chick embryos. Their experiments showed that a joint will not form between two expanding centers of chondrification unless a certain minimum length of tissue is present. When this condition was not fulfilled a continuous rod of cartilage was formed, which nevertheless resembled in contour the shapes of the normally separate parts. In some cases an abortive attempt at segmentation was observed.

Fell and Canti's results suggest that Pfitzner's observation that the characteristic shapes of separate terminal and middle phalanges are often preserved in the distal and proximal parts of the terminal phalanx of toes with two phalanges, should be interpreted in terms of a failure of segmentation rather than in terms of fusion.

Murray ('36) reviewing the evidence relating to the morphogenesis of joints, suggested that, within possible limits, the positions at which joints are formed by a skeletal blastema may be determined by the following factors:

- (a) the distances between adjacent centers of chondrification
- (b) the relative rates of extension of these centers
- (c) the relative ages at which these centers appear.

Assuming that the positions of segmentation are controlled solely by these three factors, then the initial lengths of all the segments (except the end ones) of a series derived from a single continuous skeletal blastema will also be completely determined by these variables. The lengths of the end segments will be determined by the total length of the blastema in addition to the above factors.

Figure 2 illustrates a simplified model of the operation of these suggested factors in the segmentation of a digit. This representation has neglected overall growth of the digit during chondrification, and has assumed that the rate of extension of each center is constant. Each center is shown at the origin

of a pair of diverging lines, the angle between which is proportional to the rate of expansion of chondrification. The joints are shown as being formed at the point of intersection of two of these lines originating from adjacent centers. The relative values of the variables are arbitrarily represented, except

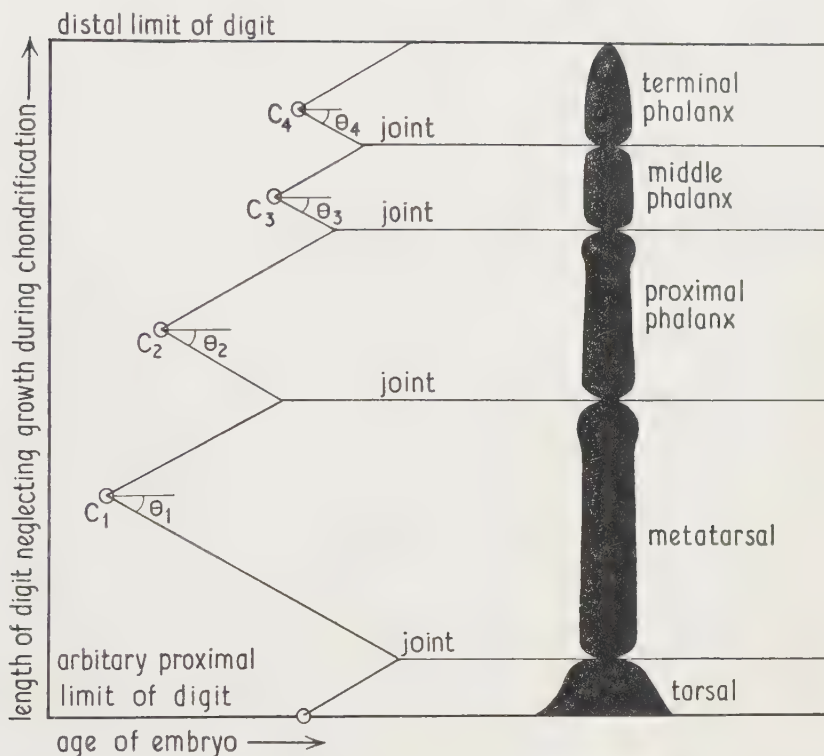


Fig. 2 Schematic representation of the factors assumed to determine position of joints. C_1 , C_2 , C_3 , C_4 represent chondrification centers with rates of expansion $2 \tan \theta$, $2 \tan \theta_2$, $2 \tan \theta_3$, $2 \tan \theta_4$ respectively.

that the centers and joints are shown as forming in a proximo-distal order. This order has been reported by Henke and Reyher (1874) and Senior ('29) in human digits, and by Hepburn (1889) in birds.

This theory of segmentation has some interest in the context of the present discussion, since it may be used to predict the

morphogenetic conditions required to produce the observed correlations between segment length, digit length and the number of ossification centers and phalanges.

The first requirement is that one, or more, of the three factors supposed to determine segment length (distances between the chondrification centers, their relative ages of appearance and rates of expansion), shall vary with respect to the length of the digit blastema at the time of chondrification in such a way as to produce the observed correlations between digit length and segment length.

The simplest of the innumerable possible relationships which could satisfy these requirements appear to be one or more of the following: that the shorter the digit blastema

(a) the closer together are the centers of chondrification, this approximation being greater between the more distal centers;

(b) the greater the relative rates of expansion of the more distal centers;

(c) the earlier the relative ages of chondrification of the more distal centers.

Each of these relationships would result in a relative proximal displacement of the more distal joints. The length of the terminal phalanx would be indeterminately related to digit length depending on the actual numerical relationships between the variables. The lengths of the more proximal segments would vary so that the shorter the digit the shorter the segments, the effect being greater the more distal the segment. How many of these more proximal segments would vary in length with respect to digit length would depend on how many of the chondrification centers were involved in the relationships suggested. If the most distal center only were affected by changes in digit length then only the length of the middle phalanx would vary in the way described.

If the observed differences in ossification and segmentation of the toes are brought about by the operation of the factors in one of the ways suggested then it follows that in toes with two phalanges the middle phalanx is represented during onto-

geny by a transiently distinct chondrification center only, or, in cases of extreme digit shortness at the time of chondrification, is probably not represented at all. This latter condition will occur when all the digit tissue distal to the proximal phalanx is chondrified by the most distal center before any intermediate center can appear. It is possible that the 1st toe, and, perhaps, those 5th toes with only a single center of ossification in the terminal phalanx are examples of this development.

SUMMARY

1. The mean lengths of the digit segments of the foot, obtained from measurements of radiographs of children and adults, are compared with respect to the presence or absence of an epiphysis of the middle phalanx, and with respect to number of phalanges in the digit.

2. It is suggested that the results are consistent with the interpretation: (a) that when the middle phalanges are less than a critical length at a certain stage of development they do not develop epiphyses, and (b) that when the length of the presumptive middle phalanx is less than a critical value the toe is segmented into two instead of three phalanges.

3. It is suggested that the correlation previously reported between the different skeletal forms and digit length, is accounted for by the correlation between the length of the middle phalanx and digit length.

4. Evidence from studies of the morphogenesis of the skeleton is discussed in relation to these hypotheses. A theory of segmentation is considered which proposes that the factors determining the positions of the joints are (a) the distances between, (b) the relative ages of appearance of, and (c) the relative rates of expansion of centers of chondrification within the blastema. The conditions required by this theory to produce the observed correlations between digit length and segment length are discussed.

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COLORIMETRIC ESTIMATION OF THE PIGMENT CONCENTRATION IN HAIR OF VARIOUS COLOR GRADES ¹

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ONE FIGURE

Hair color has long been considered a most useful criterion for distinguishing divisions of mankind and it has been recorded in many studies in physical anthropology. In most of these studies the colors have been determined subjectively, and have been assigned either names or grades determined by comparison of the hair with color charts, color wheels or standard colored hair samples. Although hair color is determined primarily by the amount and type of pigment present in the hair, there are many structural variables which enter into the production of the visible hair color. Among these are the medullation of the hair shaft, the distribution of cortical fusi and the type of cuticular scales found on the hair. Because of these variables, and because of the personal element involved in making subjective classifications of color, it has been difficult, if not impossible, for subsequent investigators to duplicate them. Many of the difficulties resulting from the use of subjective analyses of hair coloration have been discussed by Trotter ('39) in her review of hair color classification.

Attempts to devise quantitative measures of human hair color have met with little success. Gardner and MacAdams

¹ The data upon which this report is based were collected as a U. S. Public Health Service Research Fellow of the National Cancer Institute at the University of Chicago.

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('34) determined the spectrophotometric reflectance curves of 53 hair samples, ranging in color from black to blond and including various grades of red. They found that red hair is characterized by a reflectance curve which differs in form from the curves of black and blond hair, and on the basis of this difference were able to distinguish groups containing blond, brown or red hair. They found, however, that within each of these three groups there is a continuous gradation of quantitative values. Reed ('52), using a similar method of analysis for his study of the genetics of red hair, also found a characteristic difference between the reflectance curves of red and non-red hair. He reported, however, that the reflection spectrophotometer is no more efficient than the human eye in discriminating between the presence and absence of small amounts of red in darkly pigmented hair.

Russell ('39), Heidenthal ('40) and Wright and Braddock ('49) have made colorimetric studies of solutions of pigment from the hair of diverse genotypes of guinea pigs and have found that the logarithms of the optical density of the solutions are related nearly linearly to the visual color as expressed by Wright's color grades (Wright, '27). These grades were assigned by visual comparison of the hair with standard sets of hair samples, arranged in steps having a minimum perceptible increase in depth of color, and having 13 steps in the yellow series (genotype *ee*) and 21 steps in the sepia series (genotype *E*—). In both the sepia and the yellow series animals having visibly darker coats were found to have greater pigment concentrations.

The present paper reports an attempt to utilize the colorimetric method of analysis to study the relationship between the pigment concentrations of various colors of human hair and their color grades as assigned by comparison with a set of color standards. The set of standard colors used is the Haarfarbentafel of Fischer ('07), which consists of 30 numbered samples of artificial hair arranged in three series according to increasing color intensity. The color series are (1) gray-black, ranging from very light gray (No. 21) to

jet black (Nos. 27-30) and containing no yellow, brown or red, but having a bluish component increasing in intensity in the colors of the dark end of the series, (2) yellow-brown, ranging from off-white (No. 20) to dark brown-black (No. 4), with many of the colors having a reddish component and (3) a red series (Nos. 1-3).

It might be expected that Fischer's color scale would be as valuable for establishing a colorimetric scale for man as Wright's has been for the guinea pig, but this is not the case. Most laboratory animals have been inbred for many generations and have in many cases been bred for and selected for specific coat colors. As a result, many genes producing major color differences are known, and it is possible to designate the coat color of an animal and to predict the coat colors of his progeny on the basis of genotype. A guinea pig will always be of the yellow series if he is of genotype *ee* and of the sepia series if he is of genotype *E* —, regardless of the visible color of his coat. Humans, on the other hand, appear to have no major genes effecting hair color (with the exception of albino alleles, which need not concern us here). The continuous variation in human hair color appears to result from the interaction of many genes, each having a minor effect on the total coloration. Because of this the inheritance of hair color in humans is poorly understood. It is not possible to state on the basis of genotype that any given individual has no red, brown or yellow color component in his hair.

Because the pigments in all color shades of a guinea pig genotypic color series may be assumed to be of similar type, the studies which have been made of this animal have been deductive analyses. An analysis of human hair pigmentation is, of necessity, inductive. Since it is not possible to distinguish isogenic color series in man, the pigments of all human hair shades must be studied collectively, whether there be only one pigment or many present. A colorimetric reading may not represent the concentration of a single pigment in the hair solution but rather the total concentration

of several pigments. These pigments may be present in differing concentrations in solutions which give identical colorimetric readings. The readings may also reflect differences in the sizes and refractive indices of the colloidal particles of different types of pigments present in solutions from differently colored hair. Finally, all or part of the pigments measured colorimetrically may not be the coloring material of the hair, but artifacts produced by the vigorous extraction methods employed. Thus, unless all hair is assumed to have the same pigments present in equal concentrations, the colorimetric readings may not be accurate measures of the true pigment concentration. The readings must therefore be recognized as estimates only.

It is quite probable that many human genotypes may result in the production of very similar visible hair colors, and these may be classed into the same category of a hair color scale. If this is done, the grades of the color scale may not have equal validity, for the genetic variation within some grades may be much greater than within others. The relative validity of the various grades of the Fischer color scale and the reliability of subjective differentiation between color grades will be discussed.

MATERIALS AND METHODS

The hair samples used in this study are those of the twins reported by Strandkov and Diederich ('45) and by Hanna ('53). These hair samples, of approximately 100 to 300 mg each, were cut from the crown of the head of each of 254 individuals (127 twin pairs) attending high schools in Chicago, Illinois, during the school year 1942-1943. Prior to the time of cutting, the hair of each individual was classified according to color with Fischer's scale. These classifications were made by Dr. R. M. Snodgrass, then at the University of Chicago. The cut hair was placed in sealed envelopes and stored in the dark until the analysis was begun. At that time ('51), hair samples were selected at random and, without knowledge of the color grades previously assigned, were again

graded according to Fischer's standard colors by the present investigator. Of the 60 samples regraded, 8 were assigned a grade different from that assigned at the time of collection. Because the differences were not consistently in any one direction, and because the grading of loose hair might conceivably lead to different results, it was concluded that there had been little or no change in the color of the hair samples during the period of storage. The grades assigned at the time of collection have been assumed correct and are the ones referred to throughout this report.

Colorimetric analysis was made of the hair of only 174 of the original 254 individuals. Among these were 40 pairs of same-sex dizygous twins, 39 pairs of monozygous twins and 16 unpaired individuals. In the present study the hair of only one of each pair of monozygous twins has been included in order that individuals of identical genotype might not occur in any color grade. Both members of a dizygous twin pair have been included only if the hair of the two members was not of the same color grade. The number of useful hair samples was further reduced because many samples could not be definitely classified into one of the Fischer grades. This report is based upon samples of hair from 87 individuals, which are distributed as follows among the Fischer color grades:

GRADE	NO. OF SAMPLES
4 (darkest brown-black)	18 (of which two are from Negroes)
5 (brown-black)	16
6 (nut-brown)	3
7 (brown)	5
8 (light brown)	6
9 (golden brown)	1
10 (light golden brown)	2
23 (wood ash gray)	2
24 (dark ash gray)	1
25 (mouse gray)	13
26 (dark gray)	8
27 (jet black)	9 (of which 5 are from Negroes)
28 (jet black, curled)	3 (from Negroes)

The method of preparing and reading the solutions of pigment extracted from the hair has been fully described elsewhere (Hanna, '53). Briefly, the method is as follows. The individual hair samples were washed in a solution of neutral detergent to remove surface oils and dirt and were dried. Each dried sample was defatted with cold distilled ether for 8 hours in an Underwriter's type extraction apparatus and again dried. Duplicate 50 mg samples were hydrolyzed with 25 ml of 0.2 Normal potassium hydroxide by boiling under reflux for about two hours. The solutions, containing hydrolyzed hair keratin and pigments, were returned to volume and were read immediately against standard solutions of hydrolyzed pigment-free nail keratin. Triplicate readings were made of each solution at a wave length of 400 m μ , where maximum sensitivity for the hair pigments is obtained in the visible light band. The readings were made on a Coleman Junior Spectrophotometer, Model 6-A, using matched cuvettes. Readings at other wave lengths in the visible band were also made so that absorption curves might be obtained, but these are not reported here. Eight hair samples and a keratin standard solution were prepared and read at one time. The hair samples had been numbered at random before the beginning of the study, and the solutions were read at random in order that subjective bias might be avoided in obtaining the colorimetric values. It was usually not possible during the reading of the solutions to determine which of the samples were paired.

RESULTS

Since solutions of pigment from human hair are known to follow Beer's law at all wave lengths of the visible spectrum, the optical density of a pigment solution may be taken as a measure of pigment concentration in the solution. The mean optical densities of the solutions of pigment from samples of hair of 13 color grades are given in table 1. This table also gives the standard deviation of optical density and the standard error of the mean for each of the color grades.

Grades 4 and 27 are divided into Negro and Caucasian groupings. Grades 9 and 24, in which only one hair sample was available, are listed at the bottom of the column of grades. Grades 6 and 4N (the Negro group of grade 4) are listed here also, because of the great error in the determinations of optical density for these groups. The estimated variances due to colorimetry (σ_c^2) and to technical error (σ_t^2), and the estimated between-individual variance (σ_i^2) for each of the

TABLE 1

The means, standard deviations and standard error of the means of optical density of solutions of pigment from hair of thirteen color grades of Fisher ('07). Grades followed by the letter N include hair from Negroes only.

COLOR GRADE	NUMBER OF SAMPLES	MEAN OPTICAL DENSITY	STANDARD ERROR	STANDARD DEVIATION
4	16	0.3592	± 0.0184	0.0736
5	16	.2772	.0194	.0774
7	5	.2143	.0280	.0626
8	6	.2428	.0162	.0397
10	2	.2060	.0141	.0199
23	2	.0963	.0108	.0153
25	13	.2099	.0179	.0646
26	8	.1671	.0118	.0335
27	4	.4778	.0478	.0955
27N	5	.5992	.0720	.1611
28N	3	.5144	.0894	.1549
4N	2	.5136	.0049	.0070
6	3	.3359	.0166	.0228
9	1	.2297	....	....
24	1	.0720	....	....

color grades are given in table 2, together with estimates of the percentage of the total variance in each color group which is the result of errors in both colorimetry and technique (column 6), and the percentage of this total error variance which is the result of errors in colorimetry (column 7). The percentage of the total variation which results from all technical errors ranges from less than 0.2% for color grade 28 to nearly 86% for grade 6. Because of the great errors involved in the determination of colorimetric values for grades

4N and 6, these values have little validity, and they will not be considered further in this report. The percentage of the total variation which results from colorimetric errors ranges from 0.01% for grades 27N and 28 to 1.68% for grade 10 and 3.07% for grade 4N.

Neither the variation due to all errors in technique nor the colorimetric error variation are correlated with pigment

TABLE 2

Estimated variances due to colorimetric error (σ_c^2), to technical error (σ_t^2) and to variation between individuals (σ_1^2) within each of thirteen color grades, and the percentage of the total variation in each group which is due to errors in technique and in colorimetry.

COLOR GRADE	NUMBERS OF SAMPLES	σ_c^2	σ_t^2	σ_1^2	% TOTAL VARIANCE DUE TO ERROR	% ERROR DUE TO COLORIMETRY
4	16	.000002	.000077	.005104	1.52	2.53
5	16	.000003	.000054	.006272	0.90	5.26
7	5	.000003	.000007	.004347	0.23	30.00
8	6	.000001	.000134	.001012	11.77	0.74
10	2	.000006	.000010	.000341	4.48	37.50
23	2	.000003	.000002	.000419	1.18	60.00
25	13	.000003	.000130	.003734	3.34	2.26
26	8	.000002	.000019	.001233	1.67	9.52
27	4	.000003	.000046	.011620	1.22	6.12
27N	5	.000001	.000113	.099168	0.69	0.88
28N	3	.000003	.000051	.042564	0.13	5.56
4N	2	.000002	.000033	.000030	53.84	5.71
6	3	.000001	.000477	.000078	85.97	0.56
9	1	.000007	.000001	.....	....	87.50
24	1	.000002	.000045	.....	....	4.26

concentration in the hair, as measured by the colorimetric values. The correlation between pigment concentration and the proportion of total error is +.447 and between concentration and colorimetric error is +.348. The probability is greater than 0.05 in each case that the correlation does not differ from zero.

To determine whether the variation in optical density of each of the color grades may be the same the variance be-

tween individuals (σ_1^2) in each of the color grades was compared with that in each of the other grades, using the F test for the significance of the difference between variances ($F = \sigma_{i_1}^2 / \sigma_{i_2}^2$). Table 3 gives, for all possible pairs, the probability that the variation between individuals in the paired color grades is the same.

The mean optical density of each of the color groups given in the upper portion of table 1 was compared with that of each of the other groups, using the t test. The probabilities

TABLE 3

The probabilities that the variation between individuals within two compared color grades are the same. The probabilities are given only where the variation in the two color groups differs significantly. Based upon the F test ($F = \sigma_{i_1}^2 / \sigma_{i_2}^2$).

COLOR GRADE	COLOR GRADE									
	5	7	8	10	23	25	26	27	27N	28N
4	*	*	< .05	*	*	*	< .05	*	< .01	< .01
5		*	< .05	*	*	*	< .05	*	< .01	< .01
7			*	*	*	*	*	*	< .01	< .05
8				*	*	*	*	< .05	< .01	< .01
10					*	*	*	*	< .05	*
23						*	*	*	< .05	*
25							*	*	< .01	< .01
26								< .01	< .01	< .01
27									*	*
27N										*

that the mean optical densities of the compared grades are the same are given in table 4.

The logarithms of mean optical density of the color grades are plotted against grade in figure 1, together with the regression line estimated from the observations. For the yellow-brown series of Fischer the mean observed color grade (\bar{x}) is 5.5918, the mean logarithm of optical density (\bar{y}) is $-.54891 \pm .02110$ and the estimated slope of the regression line (b) is $-.03643 \pm .01240$. The regression of optical density on grade in the yellow-brown series is then $Y = \log (.2825) - .03643 (x - \bar{x})$, or $Y = -.34520 (1 + .10553x)$. For the

TABLE 4

The probabilities that the mean optical densities of compared color grades are the same. Values are given only where the means have been found to differ significantly. The values are bracketed for comparisons in which the variances of the compared color groups are not of the same magnitude (see table 3).

COLOR GRADE	COLOR GRADE									
	5	7	8	10	23	25	26	27	27N	28N
4	<.01	<.01	(<.01)	<.02	<.01	<.01	(<.01)	<.05	(<.02)	(<.05)
5		*	(*)	*	<.01	<.05	(<.01)	<.01	(<.01)	(<.01)
7			*	*	*	*	*	<.01	(<.05)	(<.05)
8				*	<.01	*	<.01	(<.01)	(<.05)	(<.05)
10					*	*	*	<.05	(*)	*
23						<.05	<.05	<.05	(*)	*
25							*	<.01	(<.01)	(<.01)
26								(<.01)	(<.01)	(<.01)
27									*	*
27N										*

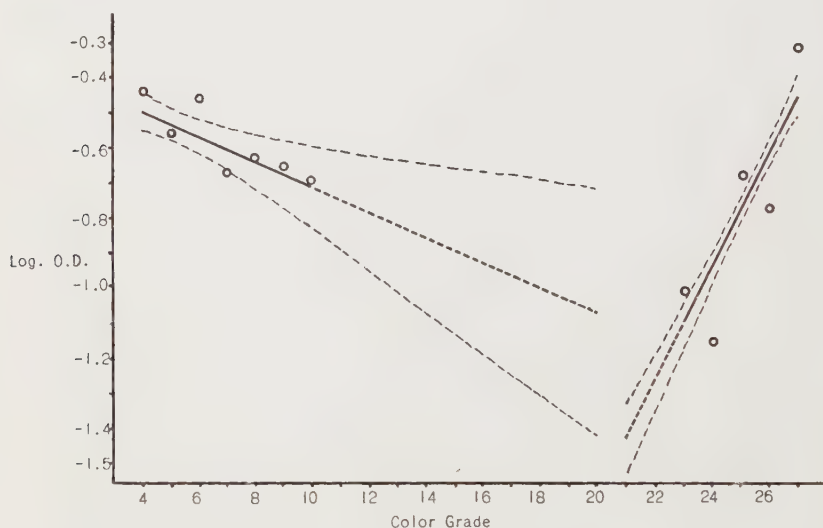


Fig. 1 The regressions of the logarithms of optical density on color grade in the yellow-brown and the gray-black series of Fischer. The mean optical densities of the color grades are shown by circles and the 90% confidence limits of the regressions are indicated by the broken lines.

gray-black series the mean observed color grade (\bar{x}) is 25.3929, the mean logarithm of optical density (y) is $-.72159 \pm .01188$ and the estimated slope (b) is $+.16112 \pm .01174$. The regression line is given by $Y = \log (.1899) + .16112 (x - \bar{x})$, or $Y = 4.81289 (.03348x - 1)$. An analysis of the

TABLE 5

Analysis of variance; observations around the fitted regression line

A. Yellow-brown series

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
Grade means around regression	$\Sigma (\bar{y} - Y)^2 = .018055$	5	.003611
Observations around grade means	$\Sigma (y - \bar{y})^2 = 1.006896$	42	.023974
Observations around regression	$\Sigma (y - Y)^2 = 1.024951$	47	
$F_{(5, 42)} = 0.1506$	$P > 0.05$		

B. Gray-black series

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
Grade means around regression	$\Sigma (\bar{y} - Y)^2 = .101962$	3	.033987
Observations around grade means	$\Sigma (y - \bar{y})^2 = .924988$	23	.040217
Observations around regression	$\Sigma (y - Y)^2 = 1.026950$	26	
$F_{(3, 23)} = 0.8451$	$P > 0.05$		

variance of the observations around the fitted regression lines is given in table 5. The probability is greater than 0.05 that a linear regression fits the observations adequately for both the yellow-brown and gray-black series. The absolute slopes of the regression lines of the two series are significantly different ($t = 2.98$, $P < .005$). Since the standard errors of the slopes are relatively great, extrapolation beyond the

points of observation (into the areas of lighter color grades in both series) is risky. In addition, the calculation of standard errors here is not strictly justified, for in the estimation of standard errors of regression coefficients it is assumed that the variance of all observed values (y) is the same. It may be seen from table 3 that this is not the case here.

DISCUSSION

It is apparent from table 1 that the optical density of solutions of pigments from the hair is roughly correlated with the visible color of the hair. However, the difference in mean concentration between grades of similar color is small, so that many grades cannot be distinguished by colorimetric analysis. Even visibly different grades, as 8 (light brown) and 26 (dark gray) or 5 (brown-black) and 10 (golden brown), do not appear to have significantly different amounts of pigment as measured by this method. The mean colorimetric values of the dark shades of hair (4 and 27) are significantly different from the means of all other grades, but those of the lighter shades do not differ significantly from each other, either within either of Fischer's color series or between them. Thus it would appear that dark hair may be more easily classified subjectively with respect to color than may light hair, and that the classification of lightly colored hair into the yellow-brown or the gray-black series may be as difficult as classification into closely related grades within either series. Fischer, in his original article ('07), noted this difficulty, stating that hair of grades 23 to 25 in the gray-black series were frequently incorrectly called "yellow blond."

The variation within dark grades of hair (Nos. 4, 5 and 27) is, in general, greater than that within light grades. The variation between individuals within grades of similar color does not differ greatly; the significant differences are generally found between grades of strikingly different hue. It would therefore appear that the lighter hair grades are more valid for classification than are the dark grades.

The regression lines given in figure 1 show graphically the difficulties of subjective classification with Fischer's table. The absolute slope of the line of the gray-black series is 4.42 times as great as that of the yellow-brown series. This suggests that, all other things being equal, it may be 4.42 times more difficult to visually differentiate hair belonging to adjacent color grades of the yellow-brown series or conversely, that visual grading on the gray-black scale may be 4.42 times as accurate as grading on the yellow-brown scale. There is considerable overlap of ranges of the logarithms of optical density of the two series, and it is in this overlapping area that it becomes difficult to distinguish between hair of the two series. From figure 1 it appears that the gray-black series may contain one color grade possessing more pigment than any color grade of the yellow-brown series, and several possessing less.

There are several factors which may, individually or collectively, be responsible for the difference in the slopes of the regression lines of the two color series. These are:

1. The steps, or the difference between colors, of the gray-black series may be greater by 4.42 than the steps between colors of the yellow-brown series. If this is so, the difference between mean optical densities in the gray-black series should be greater than the differences between means in the yellow-brown series. The variation within each of the gray-black color grades should also be greater than the variation within the yellow-brown grades. It may be seen from tables 3 and 4 that the gray-black series does not differ from the yellow-brown series in either respect. In addition, Fischer's scale is empirical, and we may assume that if intervening colors could be visually distinguished in the gray-black series they would have been included in the scale.

2. The investigators grading the hair may have biased the sample of the gray-black series (or of the yellow-brown) because of some unsuspected and unaccountable personal bias which caused them to grade hair of certain colors incorrectly. Lea ('54) has dramatically shown the effects that personal

variation may have on the subjective classification of hair color. He submitted 9 hair samples, ranging in color from albino to blue-black, for arrangement in descending order of color by 12 observers. Four different color orders were obtained; only those submitted by the three female observers were found to correspond to the order of pigment concentration established by colorimetric analysis. It is of note that all 12 observers correctly arranged the darkest and the lightest colored hairs, but that all of the male observers failed to seriate the medium shades.

It would seem that a 4-fold error would be somewhat too large to be explained by personal error alone. Because of this, and because there is no way to evaluate the errors which may be present as the result of personal bias in the classification, we are forced to disregard this as a major factor producing different regression coefficients. It may, however, be of minor importance.

3. There is some basic difference between the gray-black and the yellow-brown series which produces a true 4-fold difference between the regression coefficients of the two series. It has been suggested by Bunak ('37) that all hair colors are due to the presence of a single dark pigment (melanin), produced *in vivo* by the enzymatic oxidation of tyrosine, and that the size, number and arrangement of the melanin granules determine the color of the hair. Hausman ('27) observed that the color of human hair granules is correlated with their minor diameters and that the color of the hair *is* correlated with the size and arrangement of the granules in the hair cortex. However, he also noted that human hair might contain, in addition to granular dark pigment, a diffuse non-granular pigment, yellow or reddish in color depending upon its concentration. Saller ('27) reported a granular as well as a diffuse reddish pigment in human red hair.

Numerous workers have observed physical and chemical differences between pigments from the coats of dark and red colored experimental animals. Durham ('04), and later workers, have noted that the pigment in yellow hair is much

more soluble in dilute alkali than is pigment from dark hair. Baker and Andrews ('44) observed that the absorption curves of the hair pigments from dark and reddish guinea pigs are different in form. Serra ('46) found that the amino acid composition of the proteins with which the pigments are conjugated differ in black and yellow rabbits and Cleffmann ('53) has observed that the pigment from yellow rabbit hair reacts histochemically as a monophenol and the pigment from dark rabbit hair as a polyphenol. Rothman and Flesch ('43) isolated from the cortical granules in red human hair a red pigment which is strikingly different from melanin in its physical and chemical reactivity. This pigment has a characteristic absorption spectrum with a peak at 535 m μ . This is very close to the wave lengths of maximum curvature reported for the reflectance curves of red human hair by Gardner and MacAdams (540–550 m μ) and by Reed (530 m μ). Findings which suggest that this red pigment from human hair might be derived from tryptophan were presented by Hanna ('52) following Foster's ('51) demonstration that a yellow pigment and, under special conditions, a red pigment, could be obtained by the oxidation of l-tryptophan by enzymes in the skin of the new-born mouse.

Foster found that the skin of genetically black as well as of genetically yellow mice were capable of producing a tryptophan pigment. He observed that if the skin of a genetically black mouse was added to a reaction flask containing both tyrosine and tryptophan, the dark melanin pigment which was formed from the tyrosine completely obscured the pigment formed from tryptophan. Both Davenport and Davenport ('09) and Conitzer ('31) had earlier suggested that dark pigment which is strikingly different from melanin in its of a red pigment. However Barnicot, Birbeck and Cuckow ('55) have observed that although the concentration of dark granules in human hair appears to be correlated with depth of color, the concentration of red granules in visibly red hair is not. Rothman and Flesch ('43) had earlier observed that removal of the pigment from the red cortical granules does

not alter the visible color of the hair, and suggested (Flesch and Rothman, '46) that the pigment might play some role in the control of melanin synthesis. That the dark and light granules in hair may not be independently produced is suggested by the observation of Cleffmann ('53) that a gradual transition from yellow to black granules occurs in the melanocytes of the agouti rabbit.

Although the physiological importance of the red pigment, and its effect on the observable hair color, are far from clear, there is reason to suspect that reddish and brown hairs (Fischer's yellow-brown series) may contain pigments of a different nature, and different relative concentrations of these pigments, than does hair of colors to be found in the gray-black series. It is of interest, therefore, to see how well the results obtained here may be explained by a hypothetical multiple pigment system. Assume a system in which two pigments are responsible for the coloration of human hair. According to this hypothetical model, hair of colors which are classed in the gray-black series of Fischer's scale may contain increasing concentrations of a dark melanin pigment only, and hair of colors which are classed in the yellow-brown series may contain, in addition to increasing concentrations of melanin, varying concentrations of some yellow-red pigment. Hairs which are dark in color may then contain differing concentrations of yellow, but appear to be of the same color grade because of the masking of the yellow by the great concentration of dark pigment. The dark color grades of Fischer's scale should then exhibit greater variation in the concentration of total pigments than should the light color grades. In the hair of Negroes, which appears to have a greater concentration of pigments than hair of the same color grade from Caucasians (table 1), the masking effect may be greater because of a greater amount of dark pigment. Then the variation in Negro hair pigment concentration might be greater within any one color grade than the variation in Caucasian hair of the same grade. The differences in vari-

ation which have been observed (tables 2 and 3) may thus be explained by the presence of two pigment systems.

It has been observed that the mean colorimetric values of the dark grades differ from those of the light grades but that the lighter grade means do not differ from each other. Since the dark shades of hair are those in which masking of yellow might occur, the observed differences between these shades and the lighter shades may represent a true difference in the concentration of dark pigment, or may represent a difference in the concentration of masked pigments. The inability to distinguish between lightly colored hairs of similar shade is certainly the result of a greater number of variables effecting color in the hair. The number of visually distinguishable color shades in a dark pigment system may be taken as n , and the number in a yellow-red system as m . Then, under the multiple pigment system assumed here, the number of visually distinguishable hair color grades in the yellow-brown series will be nm if the two pigments are independent in their development. The ratio of the regression line slopes would then indicate that m may be 4 or 5, or that 4 or 5 different shades of yellow-red may be distinguished in hair of this series. The present data are insufficient to estimate the relative effect of the concentrations of pigments in determining hair color in the various color grades; they indicate only that the colors of the two series of Fischer are complex and perhaps should not be represented linearly.

The slopes of the regression lines are such that, if the grades in the gray-black and yellow-brown series are equally spaced visually and if the relationships between the logarithms of optical density and grade are really linear, the gray-black group contains hair having both a greater (No. 27) and a lesser (Nos. 23, 22, and 21) concentration of pigments than found in any hair grade of the yellow-brown series. The hair belonging to the darkest grade of the gray-black series (No. 27) may contain, in addition to a great concentration of dark pigment, variable concentrations of a completely masked yellow. At the light end of the two series, the dif-

ferences in total concentration between the series may be a measure of the concentration of the yellow pigment in the yellow-brown series hair. It is unfortunate that hair of the lighter shades was not available, for knowledge of their pigments might add much to an understanding of human hair color.

A racial difference in the concentration of pigments in the hair has been noted earlier (Hanna, '53). It is seen from tables 1 and 4 that although the hair from Negroes has a pigment concentration greater than hair of the same color grade from Caucasians, the difference is not significant on the basis of these samples. The difference appears to be constant, however, the hair of Negroes of both grades 4 and 27 having approximately the same greater concentration of pigment than the hair of Caucasians of these two grades (table 1). This difference may indicate (1) a greater relative concentration of dark pigment in the hair of Negroes than in the hair of Caucasians, (2) a greater concentration of masked pigments in Negroes, or may indicate only that (3) differences other than pigment concentration enter into the subjective classification of Negro and Caucasian hair color. Hausman ('28) has shown that hair structure, pigment granule arrangement and granule size differ in the various races of man. Perhaps a propitious combination of these factors might lead an investigator to call a Caucasian hair sample black, even though it contains much less pigment than hair of the same visible color from a Negro.

SUMMARY

1. Solutions of pigments from the hair of 87 individuals, divided among 13 color grades according to Fischer's Haarfarbentafel, have been studied colorimetrically to determine (a) the relationship between pigment concentration and color grade and (b) the relative validity of the various color grades employed in the subjective classification of hair color.

2. Hair of dark visual color grades appears to be more variable in its pigment concentration than hair of light color grades.

3. The mean colorimetric values of solutions from the hair of dark color grades are significantly greater than the means of solutions from the hair of the lighter color grades. Those of the lighter grades do not differ significantly from each other, either within the yellow-brown and the gray-black color series of Fischer or between the two series.

4. It appears that the light color grades of Fischer's scale may be more valid for classification than are the dark grades, but that it is more difficult to distinguish between hair of two grades of similar light color than between grades of similar dark color.

5. The logarithms of optical density of the pigment solutions are plotted against color grade and regression coefficients estimated. The observations are found to be represented adequately by linear regressions over the ranges studied in both the gray-black and the yellow-brown series of Fischer. The absolute slope of the regression line of the gray-black series is 4.42 times as great as the slope of the line of the yellow-brown series. The gray-black series may have one grade having a greater concentration of pigments than any grade of the yellow-brown series, and several grades having a lesser concentration.

6. The findings are best explained if it is assumed that human hair color is due to the presence of more than one type of pigment. The results are discussed in terms of two pigments; a dark pigment, responsible for the color of the gray-black series of Fischer and a yellow-red pigment, found together with the dark pigment in the yellow-brown series of Fischer.

7. The hair of Negroes is found to contain a greater concentration of pigments than the hair of Caucasians of the same color grade. This difference is constant for the color grades tested, but is not statistically significant. Whether this is the result of a greater relative concentration of dark

pigments in the hair of Negroes or to differences in structure which effect the visible color of the hair can not be determined.

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THE ROLE OF THE SUTURES IN THE GROWTH OF THE BRAINCASE OF THE INFANT PIG

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SIX FIGURES

INTRODUCTION

At the present time there are two theories concerning the growth of the mammalian braincase. According to the first (or traditional theory), the vault sutures are important sites of growth, and apposition on the sutural margins accounts for the increase in extent of the bones of the braincase. The theory is supported by clinical and surgical evidence of human skull growth (Mount, '47; Caffey, '50) and by extensive investigations of Massler and Schour ('51) and Baer ('54) on the growth of the rat vault. According to the second theory, the growth of the braincase is due to ectocranial apposition and endocranial resorption (Mijnsberg, '32; Brash, '34; Le Gros Clark, '39; and Grant, '52). Le Gros Clark ('39, p. 78) summarizes the controversy:

"The flat membrane bones in the skull vault expand by accretion on the exposed surface and absorption on the intracranial surface. It was formerly supposed that the sutural lines represent the main region of growth, but this is by no means the case."

A further complication to the understanding of skull growth is that all authorities agree that the mechanism of growth of the face and base is that of sutural increment, attributing to surface apposition only secondary thickening of the bones in these regions. Therefore, if one accepts Brash's conclusions

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on vault growth in the pig, two different processes are seemingly responsible for the final form of closely associated parts of the skull. Baer ('54) suggests that Brash's conclusions are in error due to his having studied skull growth in weaned pigs (approximately 90 days old) which are too old to show early sutural growth. Moss ('54) offers the same suggestion in his attempt to reconcile the two theories of skull growth and points out that it is most unlikely that the basic mechanisms of skull growth are different for various species of mammals, much less for different parts of the same skull.

This solution had occurred to us also and, at the time these studies were published, we were investigating a series of newborn pig skulls. Our immediate aim was to reproduce the conditions of the alizarin studies of Massler and Schour ('51) and Baer ('54), so that the growth of the infant pig skull might be compared with that of other animals. Our ultimate aim is the development of a general theory of skull growth that will be useful to those who wish to understand and compare skull differences. If anthropologists are to interpret the differences which traditional measurements of the skull describe, the measurements *must* have a known relationship to the processes responsible for adult form. Moreover, it will be impossible to study the genetics of skull form until these processes are known. Similarly, the search for the causes of phenotypic variations (such as brachycephaly) must begin with the identification of the processes which are responsible for them.

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MATERIALS AND METHODS

Day-old pigs were brought to the laboratory. Intraperitoneal injections of alizarin red-S were administered on the second and third days. Two 10 cm³ injections of a 5% solution were found necessary to insure adequate staining of the bones of the skull. The animals were fed a diet of commercial milk substitutes and grain-mash pig starters. As far as is known, the animals grew normally and rapidly and showed gains in weight comparable to those animals raised in a normal farm situation. The ages of the 18 pigs which form the basis for this study are given in table 1. Maceration and cleaning were speeded by using a 25% solution of commercial household bleach. Specimens were stored in alcohol.

TABLE 1
Terminal ages of pigs

PIG	AGE IN DAYS	PIG	AGE IN DAYS
1	7	12	44
2, 3	14	13	49
4, 5	21	14	58
6	24	15	63
7, 8, 9	28	16	65
10	30	17	72
11	35	18	77

RESULTS

Sutural growth

At the time of the alizarin injections, all surfaces of the bones of the pig skull were growing rapidly. Animals that died showed skulls that were stained completely red. Continued growth added new bone along the sutural margins at a very rapid rate. Until approximately the fifth post-natal week, there was little appositional growth on the outer surfaces of the cranial bones, even in the regions of the frontal sinuses and occipital crest. After the fifth week, appositional growth on the external table began to be rapid, and by the

eight or ninth week, it was heavy enough to obscure most of the earlier sutural growth in the regions of the sinuses and crests. Figure 1 shows the contributions of sutural growth in an animals at 49 days of age. The beginnings of localized apposition are also discernible.

An examination of figures 1-3 demonstrates the major importance of sutural growth in the vault of the young pig. The alizarin injection stains the bone red in its entirety and, since subsequent bony additions are unstained, the latter may easily be measured. Clearly, growth at the sutural margins adequately accounts for the increase during this period. Figures 1-3 also illustrate the inequality of growth on the two margins of a suture. In the pig, sutural increments are symmetrical in the internasal, metopic and sagittal (midline) sutures; but they are not equal on the two sides of the coronal, lambdoidal or circumtemporal sutures, which are responsible for increases in height and length of the skull.

In young animals, the braincase increases in length through growth in the fronto-nasal, coronal, and lambdoid sutures; increase in the width of the skull is due to growth at the metopic and sagittal sutures. Changes in height are determined by the amount of growth along the squamous and occipital sutures and along the lower border of the frontal and sphenoid bones in the orbit. As noted by Moss ('54), most of the vault sutures grow in response to cerebro-spinal fluid pressures. The sutures of the face and base, on the other hand, must be viewed as active sites of intrinsic growth and not merely as passive areas responding to the pressure of contained structures.

In the lambdoid suture, growth of the parietal bone increases the length of the skull, while the growth of the occipital bone adds to the height of the skull. Growth on the two margins of the lambdoid suture results in a change in two skull dimensions, not one. An examination of the inner and outer tables of the occiput (fig. 6) shows that the superior half of the bone is wholly ectocranial table. The endocranial table of the occiput is confined to the inferior half of the bone

and only in this region¹ do both tables contribute to the back wall of the braincase. Thus, the growth of the inferior half of the occipital bone, which articulates with the endocranial table of parietal, is more similar to that of the other vault bones than it is to the growth of the superior half of the same bone, which is related to neck muscles. This differential growth potential of the two portions of the occiput, like the unequal growth of the two contributing margins of the non-sagittal sutures, is present before birth and is probably genetic in origin.

Appositional growth on external and internal tables

The amount of appositional growth increases after the fifth post-natal week, and by the eight week, bone is being added rapidly on the external table of the roofing bones. Apposition is especially heavy over the frontal sinuses, on the brow ridges, along the temporal lines, and on the occipital crest. This accretion of bone results in the thickening of the external table of the vault and in the gradual loss of the rounded contours of the infant skull. At 9 weeks of age, long after the external table of the vault bones is covered with new, white bone, the endocranial surface still shows a marked red stain. Figure 5 shows the ectocranial and endocranial surfaces of the parietal bone of an animal that exhibits this differential apposition on the two tables of the vault. Figure 4, a para-sagittal section of the skull of an 8 week old pig, also demonstrates this and enables one to estimate the relative importance of apposition for increasing the thickness of the two tables since the original stained bone may be seen separating the later appositional bone. During the first 10 weeks of growth, there is no evidence that resorption occurs on the inner table of the bones of the vault. There is no evidence of any vault bone moving upward through apposition of bone on the outer table and resorption of the inner. Sutural growth will account for the growth changes observed in the vault during this early period.

*Resorptive changes between the two tables
of the vault bones*

The only positive evidence of resorption in this study is seen in relation to the development of the diploic spaces and sinuses. The formation of these structures is relatively late in skull development, beginning in the eighth week and continuing through the first year of life (Sisson and Grossman, '47). Throughout most of this period, apposition of bone is occurring rapidly on the external table of the vault and less extensively and less rapidly on the internal table. The frontal sinuses begin developing near the nasal margin of the frontal bone, separating the inner and outer tables of the bone as they extend backward.

The differences in the final thickness of the inner and outer tables of pig vault bones represent an extreme condition which is never observed in the rat or in man. In pig, the inner table covering the brain is almost paper thin, and the outer table, by comparison, is markedly thickened (over 1 cm thick). The alizarin stain exhibited in specimens showing the beginning of this sinus development demonstrates that resorption is occurring on the adjacent surfaces of the ectocranial and endocranial tables. This process eventually results in a marked decrease in thickness of the inner table and in a rapid excavation of the sinus space. Rapid resorption on the adjacent surfaces of the two tables of the vault, coupled with the heavier and more rapid apposition on the external surface of the ectocranial table, results in a thickening of the outer table and the excavation of a frontal sinus which eventually extends to the occipital crest. Only in the oldest animals of the present series were the beginnings of this process apparent. The preceding findings may be summarized as follows:

1. In the infant pig (1st-8th weeks), sutures are active sites of skull growth, accounting for the primary extension of the bones of the vault.
2. Thickening of the roofing bones of the vault is due to apposition on the outer and inner tables, more marked on the former than on the latter after the eighth week.

3. From the eighth week on, separation of the two tables occurs by means of resorption between the adjacent surfaces of the two tables of the vault bones.

4. The end result of these processes is that the extent and form of the ectocranial table of the vault of the older pig come to have less and less relationship to the endocranial table and the brain.

DISCUSSION

The results of this study of skull growth in the young pig agree with those of Massler and Schour ('51) and Baer ('54) on the growth of the rat skull. The events of the first 6 weeks of cranial growth in the pig closely parallel those of the first month's growth in the rat. It is now clear, as Moss ('54) and Baer ('54) suspected, that Brash's ('34) conclusions with regard to the primacy of appositional and resorptive processes of growth apply only to certain later aspects of vault development. The important difference between the description given here and that of Brash is best appreciated if his description of the sagittal suture is given and then rephrased in terms of our findings.

Brash ('34, p. 372) states that the sagittal suture "... being in the midline and therefore on the whole at right angles to the united bones, moves upward in its own plane with accretion on the outer and absorption on the inner aspects of the parietal bones." According to our findings, the movement of the suture upwards (actually an increase in the height of the vault) is the result of growth in the squamous, fronto-sphenoid, and occipital complex of sutures, and is not due to external apposition and internal resorption. Thickening is due primarily to apposition on the outer surfaces of the external table. Separation of the tables of the parietal bone is accomplished through resorption of bone from the adjacent inner aspects of the two cranial plates. Additions of bone at the sagittal suture result in an increase in skull width.

In thin-skulled animals, such as rat and man, the extent of both tables of the bones of the vault is due mostly to su-

tural growth, and the adult surface areas of the two tables are much the same. But in thick-skulled forms like the pig, the two tables will vary to such a degree that the endocranial table may have less than half the area of the ectocranial table. In the pig, the outer table of the frontal and parietal bones has migrated so far from the internal table that the extent of the roofing bones no longer bear any close relationship to the size of the brain. Certainly the brain of the adult pig could be doubled in size without changing the external shape of the vault at all. That is, the space between the two tables is more than adequate to allow such an increase in brain size, and such a postulated upward migration of the endocranial table would alter the outward appearance of the animal in no way. The term "braincase" may be quite misleading in very thick-skulled animals where the adult contours and extent of the outer table have little relationship to the brain. Over half the height of the adult pig "braincase" is compact bone, diploe, and sinuses, with the addition of muscular crests.

The relationships of brain, crests, and bone thickness may be made clearer by considering head height. In thin-skulled animals, head height is largely determined by the size of the brain and growth at the sutural margins. In animals with large temporal muscles, such as the gorilla, head height is the result of brain size and an exaggerated development of the sagittal crest. In thick-skulled forms, like the pig, bone and sinuses comprise the major part of head height. The contributions to head height made by brain, muscle crests, and thickness of bone are anatomically distinct and their relative contributions must be evaluated if skull heights of different animals are to be compared.

This research clearly demonstrates the primacy of sutural growth for the determination of adult skull form in the thin-skulled animals such as rat and man. It also emphasizes the relative independence of the two tables of the bones of the vault. The endocranial table is directly related to brain growth and development; the ectocranial table bears no relationship to the brain and develops under the influence of other factors

as stated previously. The analysis of head height in various animals stresses the necessity that structures being compared should be anatomically equivalent. This idea is not new but, as Le Gros Clark ('55) points out, has often been forgotten. Observance of this principle is not enough, however, for there are many possible levels of analysis and, as biometry and anatomy progress, an investigator's conception of what constitutes the proper units of analysis will change. It is here that the experimental analysis of growth and form supplement the comparative, descriptive, biometric approach. For example, traditionally, the anthropologist has considered the bone as the unit of study, and this point of view has been stated very recently by Bronowski and Long ('52). The limitations of this approach are illustrated by a consideration of the growth of the frontal bone as revealed by alizarin study of the pig and by human pathology. Far from being a unit, the frontal bone is divided into a number of relatively independent sections which must be distinguished if confusion in comparison is to be avoided. Increase in length of the frontal bone depends upon growth at the nasal and parietal margins of the bone. Growth at both fronto-parietal and fronto-nasal sutures is rapid during the first 6 weeks (when the brain is growing rapidly), and, at the latter suture this rate continues after this early period. Growth in the facial portion of the bone is quite independent of growth in the braincase region of the same bone. Apposition on the outer table may also be divided into apposition in response to muscle attachment and apposition in response to sinus formation. Evidence from comparative anatomy and human pathology leads to the same conclusions. A frontal bone in which the facial portion is large may be associated with a small braincase (pig) or a small facial portion may occur with a large braincase (man). In cases of hydrocephaly and microcephaly, the braincase portion of the human frontal bone varies while the development of the facial portion of the bone is normal. A measurement of the frontal bone averages two distinctive, independent pieces of anatomy, each of which grows and responds differently.

The same procedure may be used in the analysis of the growth in width of the skull. For example, growth in width of the frontal bone is due initially to growth at the metopic suture. Subsequently, most of the increase in width is appositional, especially in the region of the browridges. Again two quite different processes, functionally related to different parts of the bone, add to its breadth. Clearly, neither length, breadth, nor thickness of the frontal bone is an anatomically simple unit. The bone has individuality and while it is a simpler unit than face, base, or braincase, the alizarin preparations reveal its complex nature. From a morphogenetic point of view, the braincase portion of the frontal bone is more similar to the parietal bone than to the facial portion of the same bone.

The significance of this study for anthropology may be considered under two headings: (1) The importance of the sutures in the determination of cranial form, and, (2) The implications of this for biometry.

1. The importance of sutures

Modern man may be characterized as a thin-skulled, large-brained animal whose skull is further distinguished by small sinus development and little muscular relief. In such a skull, the relative growth potentials of the various vault sutures should determine final form to a greater extent than in any other animal.

The thinness of the human vault bones shows that appositional and resorptive processes are reduced to a minimum. This results in the rounded contours of the infant skull persisting throughout the life of man; there is little difference between the external and internal areas of the individual roofing bones of the human skull. In thick-skulled forms, sutural growth of the vault is only important for the development of the intracranial surfaces of the vault bones. The secondary processes of apposition and resorption modify the external table to an extent never seen in man or other thin-skulled forms. In thick-skulled animals the growth processes

of apposition and resorption predominate in the attainment of final form; in man they are relatively unimportant and sutural growth predominates. This suggests that study of the sutures and not bones or whole skulls will be the most useful way of analyzing the variation in human skull form.

2. Implications for biometry

On the basis of the previous remarks, it is clear that the traditional measurements of length, breadth, and height of the skull are useful only descriptively. Skull length for example, is the result of the sutural contributions of three vault bones: frontal, parietal (two margins), and occipital. Equal measurements of length may be due to different contributions of these individual bone margins. The same situation holds for the two other dimensions of the skull vault. Classifying skulls with regard to cranial indices does not make the types homologous or even comparable, as long as the sutural contributions to the measurement are not distinguished. Le Gros Clark ('55) discusses the fallacy of comparing units that are not morphologically equivalent.

Although the factors involved in phenotypic variations of the human skull are complex, the possibility exists that some of them are due to single changes in sutural contributions. For example, brachycephaly may be due to either or both of the following conditions: (1) an increase in growth at the sagittal suture (2) a decrease in growth at either (or both) the coronal and lambdoid sutures. If some skulls are round because of increased growth in the sagittal suture only, such brachycephaly may yield to genetic analysis in a way that multifactoral brachycephaly will not.

SUMMARY

At the present time there are two conflicting theories concerning the growth of the mammalian braincase. According to one, the cranial sutures are important sites of growth while, according to the other, surface apposition and internal

resorption account for most of the growth of the braincase. The skull growth of the infant pig was studied by means of the alizarin red-S vital staining technique. The study demonstrates the major role of the sutures in the growth of the braincase during the early period of brain development. Secondary growth processes of apposition and resorption are responsible for increasing the thickness of the bones and for the production of diploic and sinus spaces. The implications of this study for anthropology are discussed.

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PLATES

PLATE 1

EXPLANATION OF FIGURES

1-3 Superior, lateral, and posterior aspects of the skull of a 49-day-old pig skull. The original bone present at the time of the injection is stained red, post-injection bone is unstained. The increase in the size of the skull is due to sutural increment. The unequal contributions of the two margins of the vault sutures, other than the sagittal sutures, are observable. Secondary thickening of the bones through apposition is visible in the regions of the frontal sinuses, browridges, temporal lines, and occipital crest.

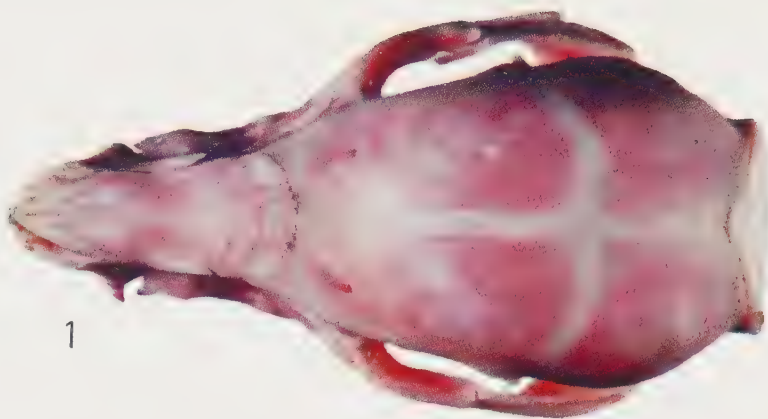


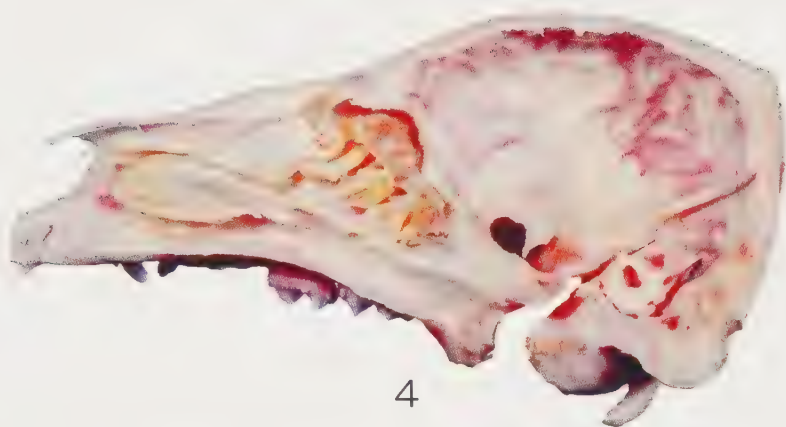
PLATE 2

EXPLANATION OF FIGURES

4 Parasagittal section of the skull of a 44-day-old pig. The original stained bone is seen between the new appositional bone on the two tables of the vault bones. Apposition is markedly heavier on the ectocranial surface than on the endocranial surface of the bones. Sutural increments on the endocranial margins of the vault sutures are visible.

5 Shows the differential rates of apposition of bone on the ectocranial and endocranial surfaces of the parietal bone of a 30-day-old pig. Appositional deposition is heavier on the ectocranial surface.

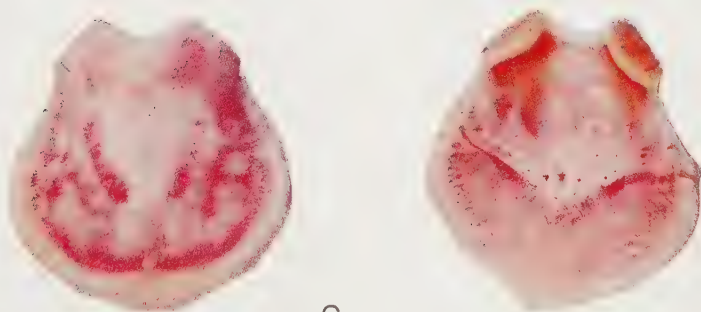
6 Gives the ectocranial and endocranial views of the occipital bone of a 30-day-old pig.



4



5



6

DEVELOPMENTAL MICROSCOPIC DEFECTS IN THE TEETH OF SUBHUMAN PRIMATES

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TWENTY-THREE FIGURES

Gross morphological observations of the dentition have contributed significantly to investigations dealing with the physical anthropology and evolution of man — *the case of the Piltdown man* notwithstanding.

Yet, when one considers the frequency with which man has been afflicted with dental pathology, and the permanency of his dental remains, it is perhaps surprising that relatively few studies have been directed towards the field of comparative dental pathology and paleopathology, especially from a microscopic standpoint.

With the aid of a histologic technique involving the embedding of teeth in methyl-methacrylate plastic and especially designed for sectioning of hard and brittle structures (Sognnaes, '47), a study was recently completed dealing with the microstructure of teeth from paleolithic, prehistoric and ancient man. Despite the presence of certain postmortem microscopic changes, which first had to be differentiated (Sognnaes, '55), it could be demonstrated that human teeth, from the time of the cave man, more often than not have suffered from quite extensive defects in the developmental microstructure (Sognnaes, '56), defects primarily attributable to failures in the mechanism of calcification.

The present study was designed to explore, for comparative purposes, the extent to which similar developmental defects may occur in the microstructure of teeth from lower primates, namely chimpanzees, gorillas, orangutans, gibbons and rhesus monkeys.

MATERIAL

The largest number of tooth specimens examined in this study were of wild chimpanzees originating from Central Africa and of wild rhesus monkeys (*Macaca mulatta*) imported from India, in addition to which we have examined the teeth of skulls from intermediary species, gorillas, orangutans and gibbons.

Chimpanzees. The chimpanzee teeth were obtained from the largest known collection of chimpanzee crania and calvaria from a single area, a total of 291 specimens. This collection was secured from Northeastern Liberia by Dr. George W. Harley of Ganda, Liberia, for the Anthropology Department and Peabody Museum, Harvard University, where Dr. Ernest A. Hooton made part of the material available to us. A previous study has dealt with gross morphologic aspects of the dentition of these chimpanzees as compared with other anthropoid and human dentitions (Schuman and Brace, '54).

The present study includes observations on the surface texture and microstructure of a total of 179 teeth from 78 skulls, 47 of males, 28 of females and three of immatures. Most of the surface replicas and ground sections were prepared from first and third permanent molars which allowed for comparison of teeth formed and calcified at two fairly distinct and widely separated periods of tooth development. In addition, observations were made on a number of permanent incisors, but this sample was smaller because these teeth were often excessively worn or missing.

Orangutans. Two orangutan skulls were made available by the Museum of Comparative Zoology, Harvard University. From these 4 teeth, 2 first and 2 third molars were prepared for ground sections.

Gorillas. The gorilla teeth were obtained from three skulls originating from the West Coast of Africa and made available to us by Mrs. B. Schevill, Museum of Comparative Zoology, Harvard University. From these skulls, 7 teeth were removed for microscopic examination, 3 first and 3 second molars and 1 incisor, all from the permanent dentition.

Gibbons. Ten gibbon teeth, two first molars, 4 third molars and 4 incisors, all permanent teeth, were obtained from three different gibbon skulls, made available by Dr. Ernest A. Hooton from the Peabody Museum, Harvard University.

Rhesus monkeys. A total of 103 teeth from 39 rhesus monkeys (*Macaca mulatta*), imported from India, were examined in ground sections, and a few as decalcified sections stained with hematoxylin-eosin, masson and azan stains. In eight of the animals we examined the microstructure of the enamel surface in shadowcast collodion replicas and a part of the material was used for a histochemical investigation reported in detail elsewhere (Wislocki and Sognnaes, '50).

PROCEDURES

Three means of observation were employed to reveal the structural details of the teeth at increasingly higher magnification. Gross characteristics of the external tooth surface were first noted by means of a dissecting microscope and by low power photographs, taken in reflected light. These methods were similar to those used by Mellanby ('29, '30 and '34) on teeth of human beings and dogs for the recording of more obvious hypoplastic defects in the surface texture of the enamel.

Microscopic surface characteristics of the teeth were examined by means of a so-called replica method, a process first applied to teeth by Scott and Wyckoff ('46). A thin film of 2% collodion is applied to the dry, cleaned tooth surface by means of a ball-ended glass rod. When the film is set and dry, it is removed by floating on water, placed on a slide and protected by a taped down cover slip. After drying for at least 8 hours, the cover slip is removed and the replica is shadowed by oblique metal evaporation under high vacuum. The angle of shadowing is such that shadows cast are twice as long as the heights of the details causing them. Since the replica is an impression of the surface, details appear in reverse, e.g., depressions in the tooth surface appear as elevations. The

replicas disclose such features as various perikymata patterns, rod-ends, laminations and micro-pits.

Histologic details were examined by means of ground sections. These were prepared by means of the plastic embedding technique mentioned above (Sognaes, '47), which served to harden and immobilize the fragile specimens during sectioning and grinding. Sections so prepared could be examined directly or be stained and remounted on glass slides for more detailed examination and permanent preservation.

RESULTS

While it is believed that the above material represents the largest collection of teeth from subhuman primates ever studied microscopically, no statistical comparisons between the various animals seemed justified because some species were inadequately sampled. Hence the results available at this time will be presented in a descriptive fashion, aside from the simple summaries tabulated in tables 1 and 2.

Chimpanzees

The *surface texture* of the chimpanzee teeth was studied grossly by observations under a dissecting microscope and by microscopic examination of shadowcast collodion replicas taken from the exposed tooth surfaces (buccal or labial). Many of the incisor teeth (particularly the maxillary) and the canines exhibited very characteristic transverse labial grooves. Examples are shown in figures 1 and 2. Yet it was found (see below) that these grooves were not necessarily accompanied by any severe pathology in the underlying microstructural quality of the teeth. In other words, the lesions appeared to represent a temporary cessation in the development of otherwise relatively normal tooth substance. The grooves were of relatively regular contour with smooth margins, similar to those described by Pedersen and Scott ('51) in Eskimo teeth. According to Colyer ('36) such "slight" transverse grooves and shallow depressions are common on the teeth of apes from the wild state.

The molar teeth, and to a lesser degree the premolar teeth, often exhibited irregularities in surface texture, such as described by Mellanby ('30 and '34) and classified as "slight hypoplasia" and "moderate hypoplasia" (fig. 3). Gross and severe hypoplastic areas were rarely to be found in the teeth of the chimpanzee. However, these wild chimpanzees were not

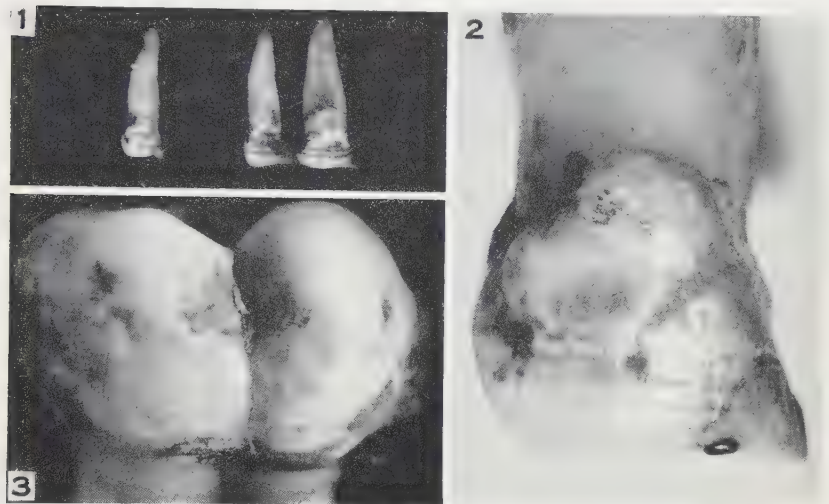


Fig. 1 Chimpanzee incisors showing marked transverse grooves on the labial surfaces.

Fig. 2 Enlarged labial view of maxillary lateral incisor of chimpanzee exhibiting several minute horizontal grooves as well as scattered roughness of the enamel surface. $\times 7$.

Fig. 3 Chimpanzee molar with slight to moderate irregularities in the external enamel texture in scattered areas of buccal surface. $\times 7$.

entirely free from dental caries. Of particular interest was the occurrence of interproximal caries of the incisor teeth. In the case shown in figure 4, a definitely carious cavity is seen near the contact point of the markedly worn distal surface of a central incisor, which also exhibits hypoplastic defects. Microscopic sections unequivocally confirmed that we were dealing with true dental caries. The *replica technique* revealed that less than 50% of the first permanent chimpanzee

molars exhibited a smooth surface texture (table 1). Approximately 20% showed relatively prominent enamel rod-ends, and about 25% of the first molars showed various irregularities in the perikymata pattern. These included "lava-like" laminations (figs. 7 and 8), and rope-like patterns and reticulations (fig. 9). The former were similar to those observed in Eskimo teeth by Pedersen and Scott ('51); the latter, shown in figure 9, do not appear to have been described previously. Less than 10% exhibited isolated micro-pits (fig. 10) suggestive of more severe, however localized, developmental disturbances.

TABLE 1
Surface texture of chimpanzee teeth
(Replica technique)

TYPE OF TEETH	NUMBER EXAMINED	SMOOTH SURFACE	PROMI- NENT ROD-ENDS	REGULAR PERIKYMATA	IRREGULAR PERIKYMATA	MICRO- PITS
M ₁	78	31	18	2	21(25%)	6
M ₃	65	4	12	10	35(50%)	4
I	36	4	8	7	14(40%)	3
Total	179	39(22%)	38(21%)	19(11%)	70(39%)	13(7%)

Similar observations of the third molars of the chimpanzee revealed a comparable frequency of micro-pits, but a much greater incidence of irregular perikymata (over 50%) than in the first molars. Only 4 of the 65 teeth studied could be classified as having a smooth surface texture. It is believed that this reflects the more genuine pattern of development because the surface irregularities of the first molars may have been erased to a greater extent by wear during their longer functional period.

The incisor teeth retained a high frequency of surface irregularities, about 30%, despite a relatively long period of function as compared to the third molars. Micro-pits occurred with the same frequency as in the first molars, about 10% of the teeth examined.



Fig. 4 Gross appearance of carious lesion on interproximal surface of maxillary incisor of chimpanzee, $\times 7$.

Fig. 5 Low power microphotograph of carious lesion extending into the dentin of chimpanzee incisor, $\times 100$.

Fig. 6 Same lesion as figure 5 at higher magnification shows invasion of the dentinal tubules and their ramification by basophilic microorganisms, $\times 600$.

Histologic sections, which were prepared of a total of 174 chimpanzee teeth, provided an opportunity to grade the developmental quality of the internal microstructure of the teeth as shown in table 2. In this table the predominating or most severe type of defect was used for classification. In other words, the interglobular dentin spaces were tabulated as such if they were present and typical with definitely separated

TABLE 2
Developmental quality of subhuman primate teeth
(ground sections)

SPECIES AND NUMBER OF ANIMALS EXAMINED	TYPE AND NUMBER OF TEETH EXAMINED	NORMAL DENTIN	GRANULAR DENTIN	AREOLAR DENTIN	INTER- GLOBULAR DENTIN
<i>Apes</i>	Incisors (42)	12 (29%)	12 (29%)	15 (35%)	3 (7%)
Chimpanzees (78)					
Orangutans (2)	1st molars (79)	23 (29%)	11 (14%)	25 (32%)	20 (25%)
Gorillas (3)					
Gibbons (3)	3rd molars (74)	36 (49%)	9 (13%)	16 (21%)	13 (17%)
86 animals	195 teeth	71 (36%)	32 (16%)	56 (29%)	36 (19%)
<i>Rhesus monkeys</i>	Incisors (18)	18	0	0	0
(<i>Macaca mulatta</i>)	1st molars (47)	45	1	1	0
	2nd molars (24)	24	0	0	0
	3rd molars (2)	2	0	0	0
	Deciduous (12)	12	0	0	0
39 animals	103 teeth	101 (98%)	1 (1%)	1 (1%)	0

globules, even though the rest of the section might contain a predominance of areolar or even slightly granular dentin.

About 60% of the chimpanzee teeth examined showed various departures from normal histologic structure in the form of various deviations from a homogenous, evenly calcified matrix. Interglobular dentin, suggestive of frank defects in calcification (fig. 11), was present in 17% of the teeth examined, the highest frequency in the first molars (25%), the

lowest in the incisors (8%). On the other hand, minor defects were more frequent in the incisors, 24% of which exhibited a granular appearance of the dentin, 38% areolar dentin. Only 35% of the first molars were devoid of dentin defects as compared to 52% of the third molars in this respect.

No attempt was made to tabulate a similar quantitative gradation for enamel structure. In general, calcification appeared relatively uniform, but unlike the monkey teeth, to be described below, there were a majority of chimpanzee teeth with accentuated incremental lines (fig. 12) suggestive of temporary developmental disturbances. Also, it could be confirmed that the tranverse grooves which were observed by gross examination of the enamel surfaces were in fact due to temporary arrests in development as indicated by microscopic evidence of deviating incremental lines.

Orangutans

The surface texture of the four orangutan teeth was first appraised grossly and by means of a dissecting microscope but did not reveal any remarkable patterns. Shadowcast collodion replicas were prepared from the surface of 6 teeth, 2 first molars, 2 second molars and 2 second premolars. One of the latter teeth showed a few micro-pits, a second molar showed irregular perikymata, and somewhat prominent rods were present in one second premolar and one second molar. Otherwise, these teeth had a relatively smooth surface texture (fig. 13).

Microscopic sections of the teeth revealed a more inferior dentin structure, three teeth having distinct interglobular dentin, one an areolar structure, others a combination of the two (fig. 14). In the internal enamel were correspondingly several distinct incremental lines, in one case showing considerable irregularities in prism arrangement. None of these irregularities extended to a point where they resulted in any severe deformity of the contour of the external enamel surface, such as the horizontal grooves noted in the chimpanzee.

Gorillas

The surface texture of seven teeth from three gorillas was examined and found to be quite smooth in four of the teeth. Two teeth, both molars, exhibited a slightly irregular perikymata pattern, whereas no micro-pits or other irregularities were noted (fig. 15). Histologically sections of the enamel showed a few cases of accentuated lines of Retzius, but in most of the teeth the enamel appeared homogenous and well calcified (fig. 16). In the dentin definite calcification defects were seen in the form of interglobular dentin in one tooth, areolar dentin in two teeth, and a granular dentin structure in two of the molar teeth (fig. 17).

Gibbons

In ten gibbon teeth from the three available skulls, the surface texture was also generally quite smooth. No distinct micro-pits were noted; the perikymata were irregular in one tooth, a third molar, but otherwise a uniform perikymata pattern was observed. Either perikymata were absent or when present were of regular configuration. A few areas of pronounced rod-ends and laminations (fig. 18) were observed.

Ground sections of the gibbon teeth revealed definite interglobular dentin spaces in two teeth, both third molars, areolar dentin in four teeth, three of which were molars, and granular dentin in three, all incisors. Some of these defects occurred simultaneously in different areas of the same teeth (fig. 19).

The enamel was of a uniform structure, but not devoid of occasional distinct incremental lines suggestive of temporary minor arrests in the developmental pattern (fig. 19).

Rhesus monkeys

In the course of the last ten years one of us (R. F. S.) has had the occasion to examine clinically and to inspect under a dissecting microscope the teeth of about one hundred rhesus monkeys, raised in India and maintained in the laboratory for brief periods prior to examination. In other words, the teeth

which have been so examined were calcified before capture while the animals lived in their wild state. In no case did these animals appear to have suffered from any of the conditions which in man so commonly leads to the development of various irregularities in the enamel surface and which we above have also observed in the chimpanzee.

This impression was further brought out by a more precise examination of eight animals whose teeth were not only inspected under a dissecting microscope but examined by means of shadowcast replicas (fig. 20). In all animals, the tooth surfaces could be classified as normal; two had a slight prominence of the enamel rod-ends, and two had somewhat more pronounced perikymata than the rest. But in no teeth were there any irregular perikymata, let alone any micro-pits. These findings are particularly significant since the animals were all relatively young, many with recently erupted permanent incisors and molars. Hence the smoothness of the enamel surface, the absence of irregularities in the perikymata pattern, the lack of prominent rod-ends and micro-pits can therefore not be attributed to secondary wear of the enamel surfaces.

In ground sections, the enamel readily transmitted light in a manner so uniform as to give the structure a homogenous glassy appearance (fig. 21). As a result, it was often difficult to perceive the rhythmic appositional pattern normally revealed by the Retzius lines. Of the 103 teeth studied, all were considered perfectly normal, and only 14 exhibited sufficiently distinct incremental lines to be graded as slightly departing from the homogenous structure characteristic of the sample in general. Only rarely could be found isolated areas of so-called pigmentations, e.g., areas which fail to transmit the full intensity of light. Upon further examination, it was noted that such areas were more penetrable to histological stains, suggesting some insufficiency of calcification attributed to a certain immaturity rather than to a pathological condition.

In the dentin observations were made regarding the presence of normal incremental growth lines of Ebner, the more

accentuated contour lines of Owen, and particularly whether or not there was any evidence of calcification defects, such as granular, areolar or interglobular dentin. Again it was noted that in the teeth of these rhesus monkeys it proved difficult to perceive any deviation from the normally expected incremental growth rings (fig. 22). The dentin exhibited a homogenous, almost glassy matrix penetrated by uniformly distributed dentinal tubules. No teeth showed any contour lines suggesting temporary arrest in development. Similarly there was no evidence of any marked calcification defects such as those reflecting themselves by the presence of interglobular dentin. Because of their lack of abnormalities, one could readily observe the finer rhythmic incremental lines in these teeth as very delicate evenly spaced rings (fig. 23).

It was of interest to note that some of the secondary dentin, which had been laid down since the capture of the animals, did exhibit some irregularity in the structure. In the two animals in which this was found it is possible that some inadequacies had existed after capture even though their diet was presumed to be adequate for normal tooth development.

DISCUSSION

The presence of externally visible hypoplasia, e.g., the transverse grooves in the anterior teeth; of internal microscopic defects, e.g. interglobular dentin spaces; and the occasional presence of grossly and microscopically demonstrable caries in the wild chimpanzee seemed surprising in view of the popular belief that animals in the wild state partake of a diet that is nutritionally ideal. Colyer ('36) suggests, however, that animals in the wild state may well experience shortages of normal food supplies for varying periods. Similar situations may perhaps also apply to relatively isolated primitive peoples, and could therefore account for such irregularities in the surface texture of teeth, which Pedersen and Scott ('51) have described in Eskimo teeth. For when we compare their observations in Eskimos and Whites with our animal material, it appears that perikymata irregularities in chim-

panzee molar teeth occurred with a greater frequency than in American White, but to a degree fairly comparable to that found in Eskimos from Alaska and Greenland. Pedersen and Scott found indeed by the same replica method that irregularities of perikymata occurred in 33% of the incisors of the Alaskan Eskimos and only 4% of the incisor in the American White. By comparison we found that 39% of the chimpanzee incisors exhibited irregular perikymata patterns. In the molar teeth these defects were somewhat less frequent in the chimpanzees than in the Eskimos, but nevertheless more common than in the American Whites studied by Pedersen and Scott.

On the basis of gross observations it is also noteworthy that Colyer found slight transverse and longitudinal grooves, together with shallow depressions to be common on the teeth of apes and monkeys from the wild state and that in a majority of cases the defects were limited to anterior teeth, especially the canines. Thus he observed pitted or grooved enamel in 11% of the Chimpanzee skulls examined, in 8% of the gorillas, in 17% of the orangutans and in 4% of the gibbons. Similar defects, as we have noted, were very much in evidence in the incisors and canines of the Liberian Chimpanzee in the present study, whereas the more generalized form of gross hypoplasia, so often seen in man was rare. Yet Colyer describes a chimpanzee skull (presumably from wild state) in the Museum of the Royal College of Surgeons, in which case the enamel was not only grooved transversely, but in which the whole surface was covered with grossly visible pits. He noted similar but less severe conditions in two other chimpanzees (one captive) and in three captive orangutans. Among the monkeys, Colyer further concludes that *Colobus* (British Museum specimen) seems liable to severe gross hypoplasia. Among the Old World monkeys, the presence of hypoplasia was reported in *Papio* and *Cercocebus*. Eleven of 538 specimens of wild *Cebus* showed hypoplasia — limited to the canines. In baboons, there also appeared to be a tendency for the hypoplastic defects to be limited to certain teeth. Widdowson ('46) also points out that the incisors of the chimpanzee in particular show hori-

zontal grooves in the enamel surface. Shaw and Auskaps ('54) failed to reveal any developmental defects in the gross appearance and microstructure of the teeth of marmosets, the twin and triplet bearing squirrel-sized New World monkeys.

With respect to histopathology, there is very limited material from which one can make quantitative comparisons. In many of the earlier studies it appears that only a single section of a single tooth was prepared from each group of animals or species studied. The remarkable pioneer work of Owen (1840-'45) with its extensive atlas on the morphology of teeth from various species was mainly concerned with normal patterns, but his observations of microscopic tooth sections showed among others a tooth section from orangutan with distinct incremental lines in the enamel.

Czermak (1850), who is generally credited with the discovery of the interglobular dentin spaces, noted that this condition — the pathological nature of which was not then appreciated — appeared to be less common and less severe in animal teeth than in the average human teeth seen by him at that time. Walkoff (1895) reported that teeth of the orangutan showed stripes of Retzius throughout the chewing surface of the enamel, but not to an extent regarded as pathological. Munch ('26) also described the lines of Retzius and interglobular dentin spaces in orangutan teeth, apparently supplied to him by Walkoff, but unfortunately, he did not mention the number of specimens or their origin, whether wild or captive. Neither did Czerwinski ('26), who observed in an unknown number of teeth of rhesus monkeys that the enamel was quite homogeneous in structure without pronounced parallel stripes. Furthermore, he noted that interglobular dentin spaces were to be found only in the root portion of the teeth in conjunction with "Tomes' granular layer."

In a more extensive study Erva ('34) similarly concluded that typical large interglobular dentin spaces were extremely rare in the crown portion of animal teeth and noted that the

occurrence in the monkey was a rare phenomenon compared to man, but not as rare as in lower animals.

Mellanby ('30) in histological observations of animal teeth found that in the rhesus monkey — with one or two exceptions — the surface texture of the enamel appeared to be perfectly smooth and that in a majority of teeth, the enamel and dentin was well calcified with no interglobular spaces. One molar from one animal and two molars from another did show minute interglobular dentin spaces and scattered areolar dentin, but both animals previously suffered from "cage paralysis" which may possibly have contributed to the defects during the captive period.

Mellanby also observed that similar defects are sometimes found in teeth of horses and ferrets, but she concludes (part III) that "As far as my knowledge goes, interglobular spaces are rare in animals living under natural conditions but in civilized man who lives under artificial conditions their presence is the rule rather than the exception" (Mellanby, '34).

In view of the limited, comparative material available to date, it would be premature to generalize regarding the relative degree of microstructural defects within various animal species or even within human groups.

At the lower level of the evolutionary scale of the subhuman primate, our present material, which appears to be the most extensive histopathological sample studied to date, indicates that chimpanzee teeth are definitely more prone to exhibit faulty microstructure than the monkeys. Moreover, in a previous histopathologic study of teeth from prehistoric and ancient man, it was demonstrated that perfect microstructure could rarely be found in human teeth even as far back as the cave man (Sogmaes, '56).

SUMMARY

By means of shadowcast replicas and ground sections, we have investigated the surface texture and microstructure of the teeth from a total of 125 wild subhuman primates, namely 78 chimpanzees, 3 gorillas, 3 gibbons, 2 orangutans, and 39

rhesus monkeys. The teeth of wild rhesus monkeys (*Macaca mulatta*), developed in their native environment in India, appeared to be remarkably free from developmental defects, the enamel surface being extremely smooth and the internal structure homogeneously formed and calcified. In contrast to these characteristics, which may be considered the standard of perfection for primate tooth structure, the teeth of anthropoids were much more prone to faulty development, which reflected itself in the presence of granular, areolar and interglobular dentin and in various irregularities of the surface texture and internal structure of the enamel. In this respect the teeth of the anthropoids were more comparable to those of man. Six percent of the wild chimpanzee skulls also had one or more teeth with caries.

ACKNOWLEDGMENT

Professor Ernest A. Hooton of Harvard University greatly stimulated the initiation of and steadily encouraged the pursuit of these and related dental investigations until his recent death.

This work was supported in part by grants from the U. S. Public Health Service and in part by the Eugene Higgins Trust. We are indebted to Drs. David B. Scott and John T. Albright for aid in shadowcasting the surface replicas of the teeth and to Mr. George Pettengill and Mrs. Emma Pettengill, and to Mr. Leo Talbot and Mr. Lawrence Brown for skilled technical and photographic assistance, respectively.

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PLATE 1

EXPLANATION OF FIGURES

- 7 Shadowcast colloidon replica from enamel surface of maxillary first molar of chimpanzee showing moderately irregular perikymata pattern. $\times 120$.
- 8 Shadowcast colloidon replica of maxillary first molar with lamination of the enamel surface. $\times 120$.
- 9 Upper first molar of chimpanzee showing irregular lamination, pronounced rod ends in the enamel surface and tendency to "rope-like" pattern. Shadowcast colloidon replica. $\times 120$.
- 10 Micro-pits in the enamel surface of chimpanzee molar. Shadowcast colloidon replica. $\times 120$.
- 11 Ground section of maxillary third molar of chimpanzee showing areolar and minute interglobular dentin and somewhat irregular and "pigmented" enamel structure. $\times 220$.
- 12 Maxillary lateral incisor of chimpanzee showing areolar and granular dentin as well as several pronounced incremental lines of dentin and enamel meeting in a V-shaped formation at the dentin-enamel junction. $\times 220$.

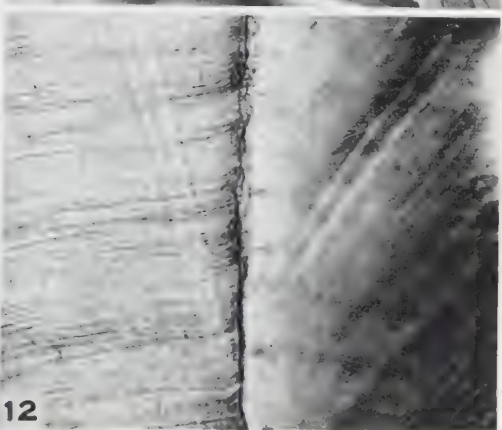
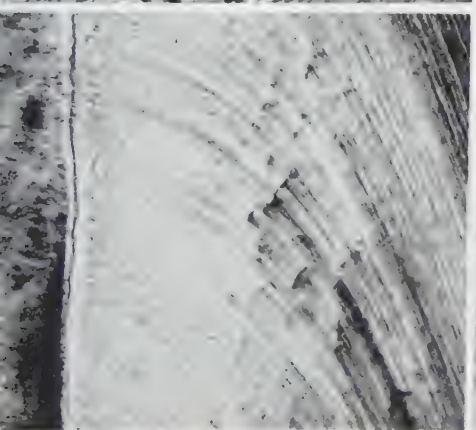
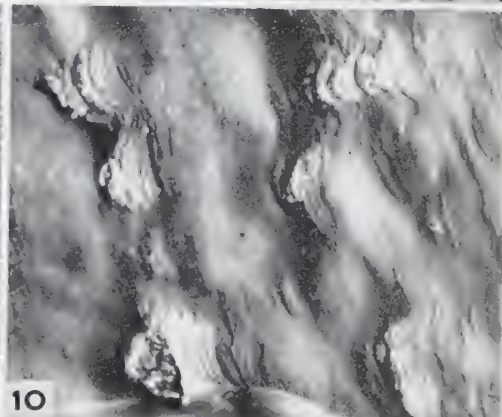
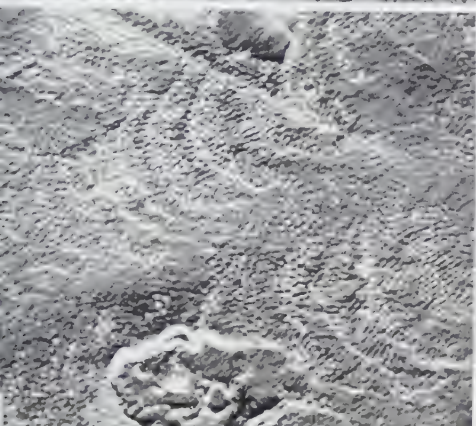
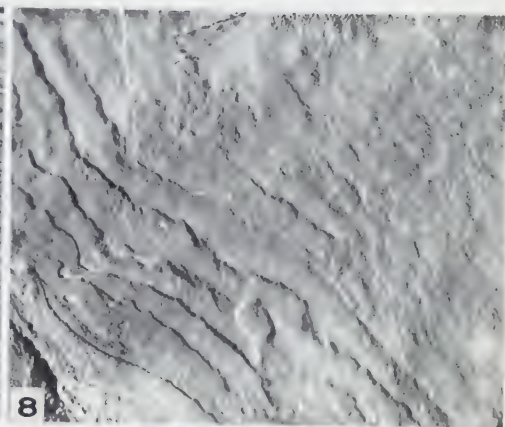
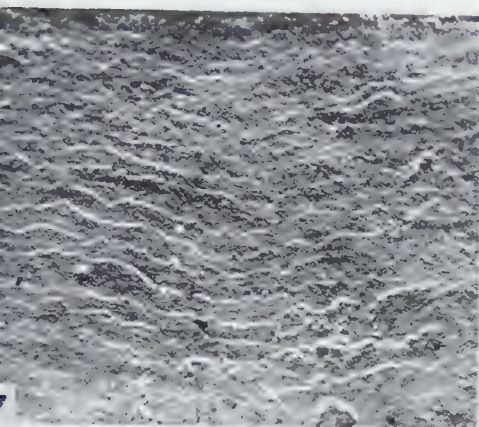
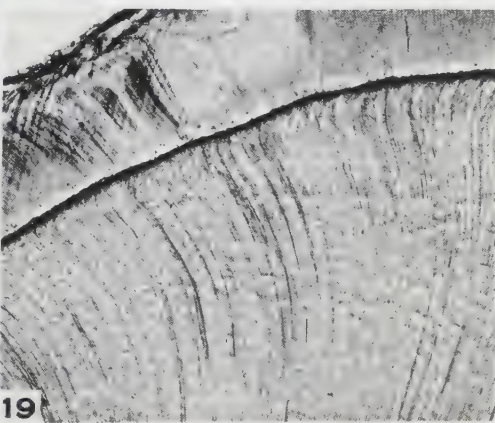
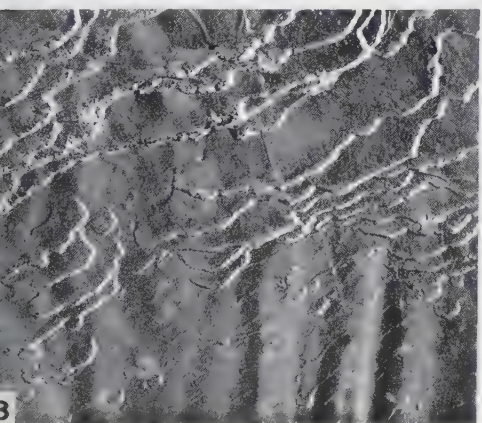
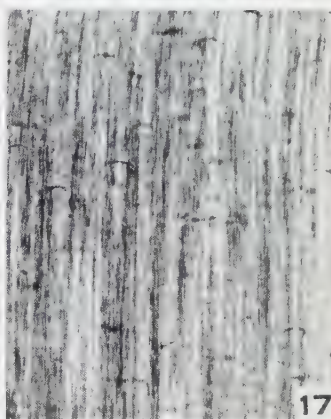
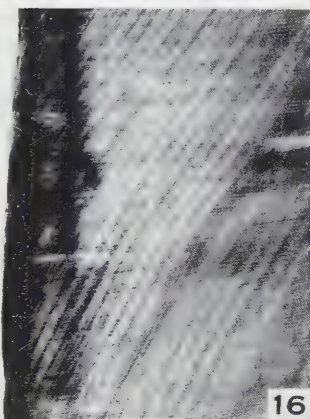
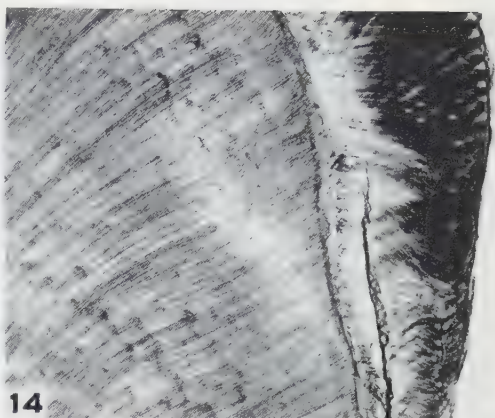
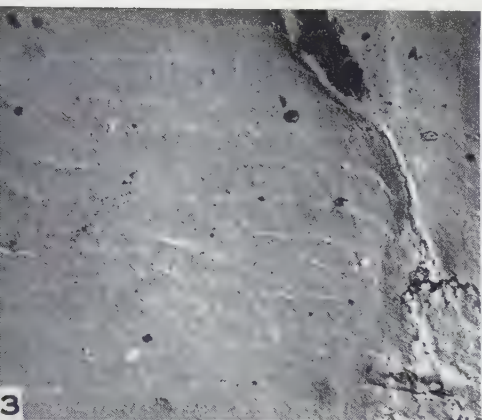
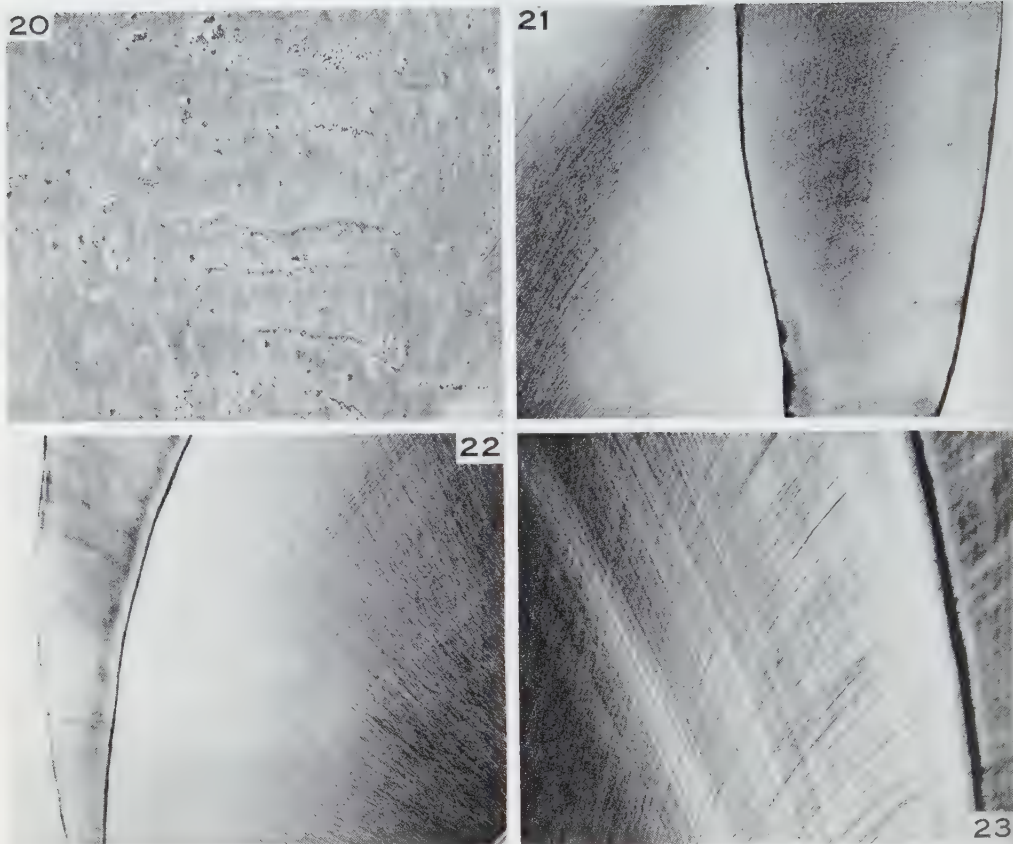


PLATE 2

EXPLANATION OF FIGURES

- 13 Maxillary left molar from orangutan showing slight tendency towards micro-pits, but otherwise quite regular perikymata pattern of the enamel surface. $\times 110$.
- 14 Ground section of orangutan molar. The dentin structure shows both areolar regions and interglobular spaces, and there is considerable irregularity in the prism arrangement and incremental pattern of the enamel. $\times 55$.
- 15 Replica from enamel surface of maxillary first molar of gorilla showing pronounced but fairly regular perikymata pattern. $\times 120$.
- 16 Ground section of enamel of maxillary third molar from gorilla showing well-defined but fairly regular incremental lines of Retzius. $\times 110$.
- 17 Ground section of maxillary first molar of gorilla showing areolar and granular structure with scattered minute interglobular dentin spaces. $\times 120$.
- 18 Replica of Gibbon tooth with considerable irregularity and lamination of the perikymata. $\times 110$.
- 19 Ground section of maxillary third molar from male gibbon with generally granular dentin and some deviation in the incremental pattern of the enamel. $\times 55$.





- 20 Replica of the enamel surface from maxillary central incisor of rhesus monkey. The perikymata pattern is barely noticeable because of the smoothness of the enamel surface. $\times 110$.
- 21 Ground section of first maxillary molar of rhesus monkey. Perfect microstructure with completely homogenous calcification of dentin and enamel. $\times 55$.
- 22 Ground section of first maxillary molar of rhesus monkey. Perfect calcification and regular formation. Notice regular pattern of Ebner's growth lines. $\times 55$.
- 23 Ground section of maxillary incisor of rhesus monkey. The incremental lines in dentin are regularly arranged with no evidence of granular areolar, or interglobular dentin. $\times 55$.

THE BLOOD GROUP GENES OF THE CREE INDIANS AND THE ESKIMOS OF THE UNGAVA DISTRICT OF CANADA

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This report deals with the blood group genes of the natives living in the James Bay area, i.e. Cree Indians; and, on the eastern coast of the Hudson Bay, the Eskimos. This work was carried out at Moose Factory and is a continuation of the study under the aegis of the National Museum of Canada on the Indians of Canada.

There are 4270 Cree in the area, living in ten settlements.¹ There has been contact with Whites since late in the 17th century, Rupert's House, Moose Factory and Albany having been important posts and distribution centers of the Hudson's Bay Company since that time. In the last half century more and more Whites have come into the area, with an increasing rate of miscegenation. The data here presented, based on a sample of approximately 4% of the population, are simply a reflection of that population as it exists today. They cannot be taken to represent the Cree in a pure-bred state or the Cree at large, for they extend over an enormous area. A number of additional studies will have to be made before we will have a blood group genetic picture of the Cree. In the present study, as in our earlier ones, we took the greatest care we could, not to include close relatives, and also not to include those with as

¹ Population of Cree settlements on James Bay, March 1955. Ft. George 816, Albany 750, Attawapiskat 739, Moose 573, Rupert's House 562, Old Factory 299, East Main 212, Great Whale 180, Nemeska 117, New Post 22.

much as one-quarter White blood in our gene frequency material. That we were completely successful in either respect is to be doubted; the Indians in this area seemed particularly disinterested in or unaware of their family trees. There is little documentary evidence available, but Bishop Neville Clark very kindly loaned us the Anglican church records of births, marriages and burials, which did prove helpful.

A sample of 64 Eskimo was drawn from 7 settlements which are situated along the eastern coast of Hudson Bay. (Eskimo settlements. Old Factory, Richmond Gulf, Great Whale, Povungnetuk, Belcher Is., Ft. Harrison, Ft. George.) Our information is that intermarriage between the settlements is common; in some of them it is almost obligatory. There has been very little intermarriage between Eskimo and White; practically none between Indian and Eskimo.

SERA AND METHODS

In the following the serum is described first, the method is given after the semicolon.

The *ABO* system. One each, high titre, avid anti-*A* and anti-*B*; capillary. One commercial anti-*A1* (*absorbed B*); open well slide.

The *MNSs* system. Two commercial anti-*M* and one from Dr. J. J. vanLonghem, all three used in parallel; capillary. Two commercial anti-*N* in parallel; open well slide. One anti-*S* (no. 63), courtesy Dr. L. K. Diamond; capillary. One anti-*U* (anti-*S* + *s*), provided by Dr. T. J. Greenwalt; indirect Coombs.

The *Rh* system. One anti-*C* + *C^w*; capillary. One anti-*c* for all bloods; capillary. Second confirmatory anti-*c* on all *C*-positive bloods; capillary. Third confirmatory anti-*c* on all bloods apparently containing *R_z* (*CDE*); indirect Coombs. One anti-*D* for all bloods; capillary. Those negative or weak with this serum were tested with a second saline anti-*D*; capillary, and two anti-*D*; indirect Coombs. One anti-*E*, giving dosage effect; capillary. One anti-*e* for all bloods; capillary. Second confirmatory anti-*e* on all *E*-positive bloods; capillary.

Two anti-*f* in parallel, one derived from anti-*c* + *f* by absorption with *cDE* · *cDE* cells, the other from anti-*e* + *f* by absorption with *CDe* · *CDe* cells; capillary. There was no discrepancy in the reactions with any of the sera.

The *P* system. One naturally occurring human anti-*P*; capillary at refrigerator temperature.

The *Kell* system. Two anti-*K* (Ram, Mar) with all bloods; capillary and indirect Coombs. One anti-*K* (Zab) with all bloods; capillary (this serum reacts only in saline). Two anti-*K* (Swa, Fed) with all 'O' bloods; capillary, also with 78 of these; indirect Coombs. One anti-*K* (R. B.) provided by Dr. F. Ottensooser, with 78 of 'O' bloods; indirect Coombs. The five anti-*K* sera (Ram, Mar, Zab, Swa, Fed) are all derived from women in the child bearing age whose husbands are *Kell*-positive and who have been either transfused with *Kell*-positive blood (Zab, Fed), sensitized by pregnancy alone with resulting hemolytic disease in the offspring (Mar, Swa), or both (Ram). Ram and Mar were originally identified as anti-*K* sera using a panel selected by the anti-*K*, Hellewell, of Mourant. In a gene frequency study of whites using Ram (Lewis, Chown and Peterson, '55) there was no discrepancy from the results of Ikin et al. and of Parkin, recorded by Mourant ('54). The serum provided by Dr. Ottensooser is the one reported by him in 1953, and used by Pantin and Junqueira ('52) for their study of Brazilian Indians. A control *Kell*-positive sample was set up each day.

The *Duffy* system. One anti-*Fy^a* developed in a woman as the result of transfusion and possibly pregnancy (Robinson et al., '53); indirect Coombs.

The *Lewis* system. One anti-*Le^a*; short albumen.

The *Jay* system. One naturally occurring anti-*Tj^a* (ELL.), kindly provided by Mr. Ronald B. Roy; capillary, with 'O' bloods only.

RESULTS

The results for the *ABO*, *MNSs*, *Rh*, *P*, *Duffy* and *Lewis* systems for the Indians are set out in tables 1 to 8. For the

rest, 166 tested were all *Kell*-negative, 119 tested were all *Tj* (a +) and 144 tested were all *U*-positive.

The results for the *ABO*, *MNSs*, *Rh* and *P* systems for the Eskimos are set out in tables 9 to 14. For the rest, 64 tested were all *Kell*-negative, *Fy* (a +) and *Le* (a —), 51 tested were *U*-positive and 24 tested were *Tj* (a +).

TABLE 1
The ABO groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	Gene frequencies
<i>O</i>	119	.7169	.7191	119.37	
<i>A</i> ₁	41	.2470	.2477	41.12	<i>O</i> .8480
<i>A</i> ₂	2	.0120	.0121	2.01	<i>A</i> ₁ .1343
<i>B</i>	3	.0181	.0181	3.01	<i>A</i> ₂ .0071
<i>A</i> ₁ <i>B</i>	1	.0060	.0028	0.46	<i>B</i> .0106
<i>A</i> ₂ <i>B</i>	0	.0000	.0001	0.02	1.0000
	166	1.0000	.9999	165.99	

TABLE 2
The MN groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	Gene frequencies
<i>MM</i>	84	.5091	.5378	88.74	
<i>MN</i>	74	.4485	.3911	64.53	<i>M</i> .7334
<i>NN</i>	7	.0424	.0711	11.73	<i>N</i> .2666
	165	1.0000	1.0000	165.00	1.0000

TABLE 3
The Ss groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	Gene frequencies
<i>S</i> +	101	.6084	<i>S</i> .3742
<i>S</i> —	65	.3916	<i>s</i> .6258
	166	1.0000	1.0000

TABLE 4
The MNSs groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	
<i>MMS</i>	64	.3879	.4097	67.61	<i>Gene frequencies</i>
<i>MMs</i>	20	.1212	.1280	21.12	
<i>MNS</i>	36	.2182	.2003	33.05	
<i>MNs</i>	38	.2303	.1908	31.48	
<i>NNS</i>	0	.0000	.0000	0.00	
<i>NNs</i>	7	.0424	.0711	11.73	
	165	1.0000	.9999	164.99	

TABLE 5
The Rh groups of the Cree

PHENOTYPE	POSSIBLE GENOTYPE	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	
<i>CcDEe</i>	$\left\{ \begin{array}{l} R_1R_2 \\ R'R_2 \\ R_zr \end{array} \right\}$	67	.4036	.3935	65.31	<i>Chromosome frequencies</i>
<i>CCDee</i>	$\left\{ \begin{array}{l} R_1R_1 \\ R_1R' \end{array} \right\}$	42	.2530	.2816	46.76	
<i>ccDEE</i>	R_2R_2	20	.1205	.1345	22.33	
<i>CcDee</i>	R_1r	18	.1084	.0807	13.40	
<i>ccDEe</i>	R_zr	8	.0482	.0602	9.99	
<i>CCDEe</i>	$\left\{ \begin{array}{l} R_1R_z \\ R'R_z \end{array} \right\}$	3	.0181	.0200	3.32	
<i>CcDEE</i>	R_2R_z	5	.0301	.0140	2.32	
<i>ccddee</i>	rr	1	.0060	.0067	1.11	
<i>Ccddee</i>	$R'r$	1	.0060	.0067	1.11	
<i>CCddee</i>	$R'R'$	1	.0060	.0017	0.28	
<i>CCDEE</i>	R_zR_z	0	.0000	.0004	0.07	
		166	.9999	1.0000	166.00	

TABLE 6

The Pp groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	Gene frequencies	
P +	97	.8291	P	.5866
P —	20	.1709	p	.4134
	117	1.0000		1.0000

TABLE 7

The Duffy groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	Gene frequencies	
Fy(a+)	155	.9394	Fy ^a	.7538
Fy(a—)	10	.0606	Fy ^b	.2462
	165	1.0000		1.0000

TABLE 8

The Lewis groups of the Cree

GROUP	NUMBER	FREQUENCY OBSERVED	Gene frequencies	
Le(a+)	1	.0060	Le ^a	.0775
Le(a—)	165	.9940	Le ^b	.9225
	166	1.0000		1.0000

TABLE 9

The ABO groups of the Eskimo

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	Gene frequencies	
O	26	.4063	.4028	25.78	O	.6347
A ₁	37	.5781	.5733	36.69	A ₁	.3533
B	1	.0156	.0153	0.98	B	.0120
A ₁ B	0	.0000	.0085	0.54		1.0000
	64	1.0000	.9999	63.99		

DISCUSSION

In the Indians the *MN* system shows some discrepancy between expected and observed. The series was well controlled in so far as serum reactions are concerned since each day we tested some Indian and some Eskimo bloods, and the Eskimo

TABLE 10

The MN groups of the Eskimo

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	<i>Gene frequencies</i>	
<i>MM</i>	26	.4062	.4204	26.91	<i>M</i>	.6484
<i>MN</i>	31	.4844	.4560	29.18		
<i>NN</i>	7	.1094	.1236	7.91	<i>N</i>	.3516
	64	1.0000	1.0000	64.00		
						1.0000

TABLE 11

The Ss groups of the Eskimo

GROUP	NUMBER	FREQUENCY OBSERVED	<i>Gene frequencies</i>	
<i>S +</i>	5	.0926	<i>S</i>	.0474
<i>S —</i>	49	.9074	<i>s</i>	.9526
	54	1.0000		1.0000

TABLE 12

The MNSs groups of the Eskimo

GROUP	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	<i>Gene frequencies</i>	
<i>MMS</i>	4	.0741	.0754	4.08		
<i>MMs</i>	17	.3148	.3210	17.33	<i>MS</i>	.0630
<i>MNS</i>	1	.0185	.0467	2.52	<i>Ms</i>	.5666
<i>MNs</i>	25	.4630	.4197	22.66	<i>NS</i>	.0000
<i>NNS</i>	0	.0000	.0000	0.00	<i>Ns</i>	.3704
<i>NNs</i>	7	.1296	.1372	7.41		1.0000
	54	1.0000	1.0000	54.00		

TABLE 13
The *Rh* groups of the Eskimo

PHENOTYPE	POSSIBLE GENOTYPE	NUMBER	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	
<i>CcDEe</i>	R_1R_2	31	.4844	.4858	31.09	
<i>CCDee</i>	R_1R_1	15	.2344	.2344	15.00	Chromosome frequencies
<i>ccDEE</i>	R_2R_2	17	.2656	.2518	16.12	<i>CDe</i> (R_1) .4841
<i>ccDEe</i>	$\left\{ \begin{array}{l} R_2R_0 \\ R_2r \end{array} \right\}$	1	.0156	.0141	0.90	<i>cDE</i> (R_2) .5018
<i>CcDee</i>	$\left\{ \begin{array}{l} R_1R_0 \\ R_1r \end{array} \right\}$	0	.0000	.0136	0.87	<i>cDe</i> (R_0) or/and .0141 <i>cde</i> (r)
<i>ccDee</i>	$\left\{ \begin{array}{l} R_0r \\ R_0R_0 \end{array} \right\}$	0	.0000	.0002	0.01	1.0000
<i>ccddee</i>	rr	64	1.0000	.9999	63.99	

TABLE 14
The *Pp* groups of the Eskimo

GROUP	NUMBER	FREQUENCY OBSERVED	Gene frequencies
$P +$	12	.5000	P .2929
$P -$	12	.5000	p .7071
	24	1.0000	1.0000

bloods fit very nicely in the *MN* system. The possibility that there exists a variable *M* or *N* in the Indians has not been excluded; the reactions with the three anti-*M* sera and the two anti-*N* were consistent and clear-cut. Chance sampling error is possibly the explanation.

Two notes may be made about the *Rh* system. As stated we had two anti-*f* sera. These were used on all bloods that were *CcDee* and *ccDEe* in the hope that we might distinguish between *CDe* · *cDeF* and *CDe* · *cdef* and between *cDE* · *cDeF* and *cDE* · *cdef*. All were *f*-positive. From Race and Fisher's original hypothesis of cross-over occurring for the rare chro-

somes one expects to find the frequency of *CDE* approximately equal to that of *cDe*. We estimated the frequency for *CDE* at .0189. We did not isolate *cDe* in a genotype that would distinguish it from *cde* so that our estimate for it is zero. Some of the chromosomes that we call *cde* and estimate at a frequency of .0821 however are probably *cDe*. If Sanger et al. ('53) are right about the *Rh* genes *F* and *f*, nearly all the chromosomes *cDe* in this population, derived as it presumably is primarily from *CDeF* and *cDEF*, should contain *F*, i.e. should be written *cDeF*, and should not react with anti-*f*. That we did not find any *f*-negative may only depend on the small number tested.

In studying a family in which the *Rh* chromosome *Cde* occurred we found that quantitative titration with anti-*D* and anti-*e* + *f* allowed us to recognize the heterozygotes *CDe* · *Cde* and *cDE* · *Cde*. This observation will be the subject of a separate note; however we might mention that had not exhaustive work on genealogies been done the incidence of *Cde* in this population would have been recorded at a much higher figure. Six individuals were encountered who were *Cde* · *Cde* and one who was *Cde* · *cde*.

Special care was taken with the tests for the *Kell* factor because of the incidence of 14.91% *Kell*-positive in Chippewa Indians (Matson, Koch and Levine, '54), and 10.17% *Kell*-positive in Brazilian Indians (Pantin and Junqueira, '52). No *Kell*-positive was found in the present series nor have we ever found a *Kell*-positive in previous studies on the Indians of Canada (Chown and Lewis, '53, '55).

ACKNOWLEDGMENT

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THE PTERION IN THE AUSTRALIAN ABORIGINE

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FIVE FIGURES

INTRODUCTION

Ashley-Montagu ('33) painstakingly reviews the voluminous literature on the pterion and summarizes his own observations on the primates and on ethnic groups of man. To avoid needless repetition unspecified references in the present study to the older authors can be traced through this source. He quotes workers before the turn of the century as having already recorded details of over 400 Australian aboriginal skulls. As the number of these in European collections at that time must have been relatively small this must include some overlapping.

Collins ('26) records findings from 103 Australian skulls, but these are observations of dioptographic tracings and not original skulls. Fenner ('39) records findings from 766 Australian skulls, but only as part of a much larger investigation and so is necessarily incomplete.

The 4 methods of contact between the contiguous bones at the pterion are spheno-parietal (fig. 1 a), fronto-temporal (fig. 1 b), stellate (fig. 1 c), and epipteric bone or bones (fig. 1 d).

MATERIAL AND METHODS

Australian aboriginal skulls examined numbered over a thousand. Those in which the pterion pattern could not be clearly identified owing to breakage or advanced synostosis

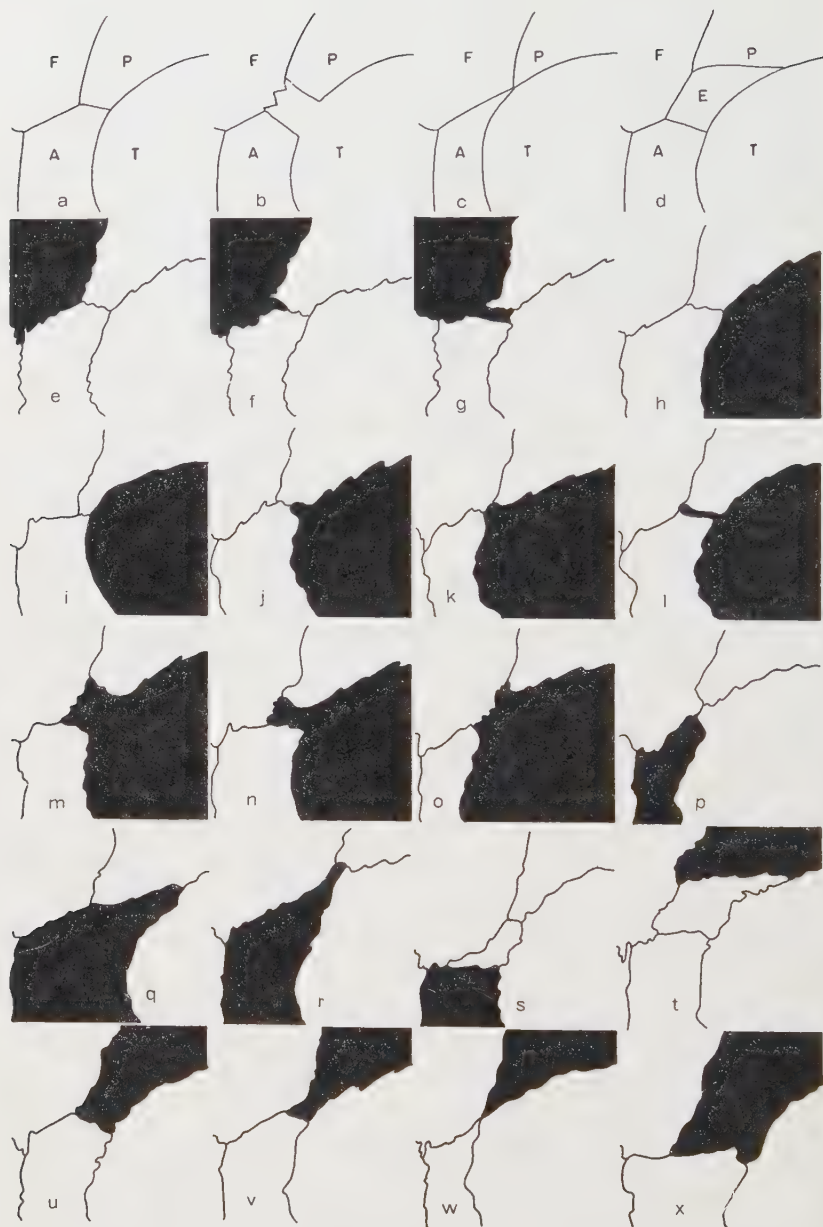


Fig. 1 Types of pterion contact and variation in the pteric bones. Scale, \times Approx. $\frac{1}{2}$.

were rejected. As Abbie ('50) has shown, pterion closure in the aborigine tends to occur early so that the rejection rate was relatively high. Nevertheless, data were recorded from 368 skulls, of which 28 are from the Department of Anatomy, University of Adelaide, and 340 from the South Australian Museum.

Sex of skulls was recorded according to the observer's judgment. Age was determined according to eruption of teeth and the degree of dental attrition (Campbell, '39; Abbie, '50).

Illustrations throughout are of the left side. Where only right-sided examples were available, they have been drawn reversed to facilitate comparisons.

OBSERVATIONS

The pteric bones

While keeping in mind that variation in any of the pteric bones must be accompanied by reciprocal variation in one or more of the others, each bone will be described separately.

The frontal bone. The coronal and fronto-alisphenoid sutures commonly formed an angle of about 130° at the pterion (fig. 1 e). In 40 cases this angle was sharpened by growth of frontal bone along the alispheno-parietal suture (fig. 1 f), and in three this growth was exuberant enough to effect a fronto-temporal contact (fig. 1 g).

The squamous-temporal bone. The suture separating the squamous-temporal from the parietal and the alisphenoid formed a regular curve in about half the cases (fig. 1 h). In the other half the area of the squamous projected slightly towards the pterion, distorting the smoothness of the curve of the suture, and forming an antero-superior angle to the squamous-temporal (fig. 1 i). In more than 60 pteria this angle was sharpened by growth of bone along the pterion suture reducing the length of the spheno-parietal contact (fig. 1 j). This bone growth effected a small fronto-temporal contact in 9 cases, in three where the adjacent parietal and

alisphenoid were narrow (fig. 1 k), and in 6 where the growth was unusually exuberant (fig. 1 l).

Another group of cases, numbering 50, had a larger fronto-temporal contact. In these the most common appearance (30 cases), was a quadrangular extension of the squamous temporal, the three free borders articulating with the frontal, parietal and alisphenoid respectively. The sutures forming the sides were straight or curved and simple, the suture with the frontal was usually serrated (fig. 1 m). In 13 pteria the process was constricted from side to side by hyper-development of parietal and alisphenoid, decreasing the length of the fronto-temporal contact (fig. 1 n), and in 7 the process was constricted in the opposite direction by narrowness of the parietal and alisphenoid, increasing the length of fronto-temporal contact (fig. 1 o).

The alisphenoid bone. Narrow and broad, high and low alisphenoids were seen. Excessive narrowing, as noted in the previous observation, was a factor in producing fronto-temporal contact (fig. 1 p), while excessive breadth lengthened spheno-parietal contact (fig. 1 q). A prolongation extended upwards between the frontal and temporal bones in high alisphenoids (fig. 1 r), while an epipteric bone often accompanied a low alisphenoid (fig. 1 s).

The parietal bone. The part in relation to the pterion is the anterior inferior angle. Variation was seen to be largely reciprocal with the alisphenoid. Height was often associated with an epipteric bone (fig. 1 t). A downward prolongation often extended between the frontal and temporal bones to meet a low spheno-parietal suture. This prolongation was sometimes broad (fig. 1 u), sometimes narrow (fig. 1 v), and very occasionally effected a stellate contact (fig. 1 w). Occasionally the prolongation was very broad (fig. 1 x).

The epipteric bones

Pteria with contact completed by epipteric bone or bones numbered 135, 68 right and 67 left. Sixty-two were mutually

paired in 31 skulls, 62 were paired with spheno-parietal contacts, and 11 with fronto-temporal contacts.

Basic types. Great variability was seen in shape and extent of epipteric bones, but they were found to fall into 5 basic types.

Type I (17 pteria, 7 right and 10 left; one pair and 15 unilateral; all single bones) articulated with parietal, temporal and alisphenoid only, and occupied territory usually held by parietal and alisphenoid (fig. 2 a).

Type II (48 pteria, 27 right and 21 left; three pairs and 42 unilateral; all single bones) articulated with all 4 pteric bones, and occupied territory usually held by parietal, and alisphenoid and frontal bones. The epipteric-parietal, and epipteric-alisphenoid sutures both met the curve of the squamous-temporal at approximately a right angle (fig. 2 b).

Type III (15 pteria, 7 right and 8 left; one pair and 13 unilateral; all single bones) articulated with all 4 pteric bones but was more highly placed in the skull than Type II and so was always associated with a very high alisphenoid. It occupied territory usually held by parietal and frontal, displacing the former much more than the latter. The epipteric-alisphenoid suture, as in Type II, met the curve of the squamous-temporal at approximately a right angle, but the epipteric-parietal suture met this curve at approximately a tangent with its highest point (fig. 2 c).

Type IV (54 pteria, 26 right and 28 left; 13 pairs and 28 unilateral; 13 multiple and 41 single) in position, the area of pteric bones it replaced, the disposition of its sutures, and its usual size appeared to correspond to its being a combination of Types II and III (fig. 2 d).

Type V (one pterion, one right; unilateral; multiple) similarly appeared to correspond to its being a combination of Types I and III (fig. 2 e).

Variation. All 5 types of epipteric bones are more variable in shape and extent than other skull bones. Three factors appear to cause this: (1) variation in size, uncorrelated with skull size; (2) variation in sutures, the epipteric bone en-

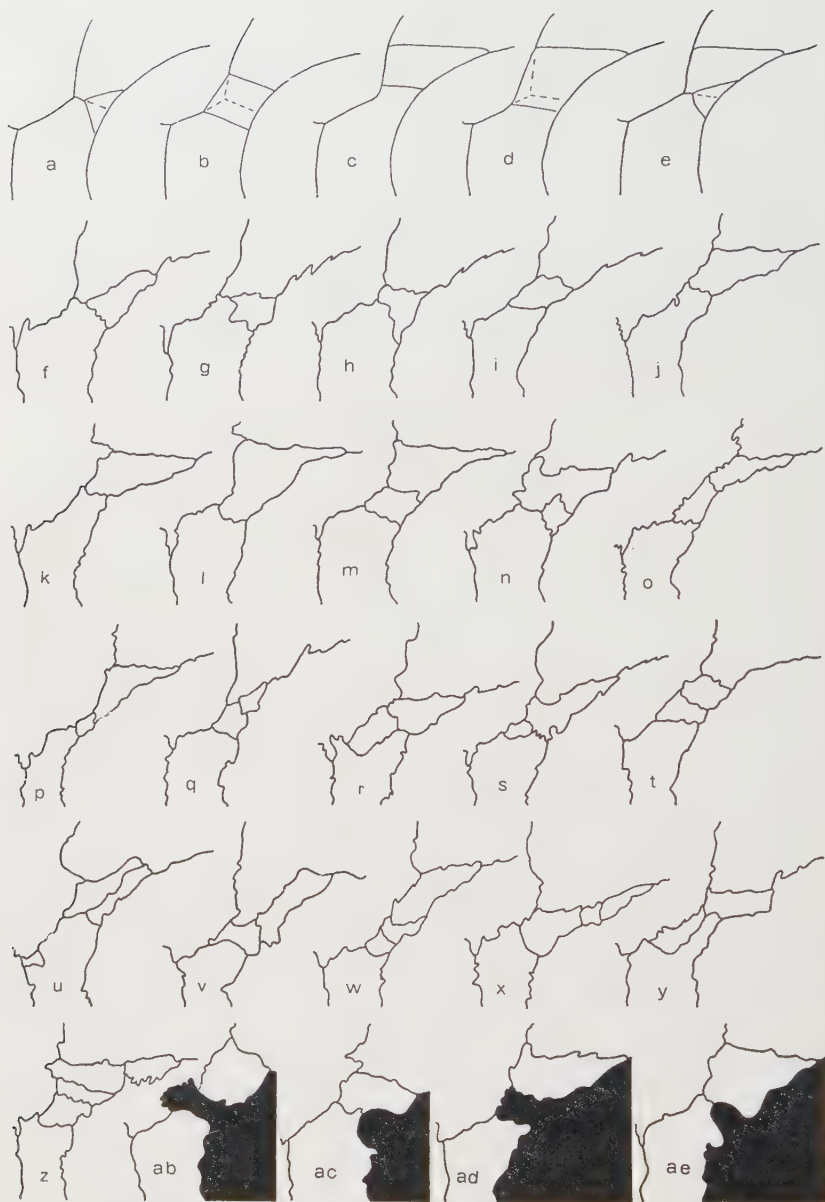


Fig. 2 Types and examples of epipterice bones, multiple epipterice bones, and combined types of pteria. Scale, \times Approx. $\frac{1}{2}$.

croaching on one or other of the pteric bones, or being encroached on by them; (3) growth by the epipterice bone along the sutures which meet it, in the manner already described in variation in the frontal and parietal bones.

Examples. In figure 2, Type I is represented in f and g; Type II in h and i; Type III in j and k; Type IV in l and m; and Type V in n. While great variation is evident, analysis according to the three causative factors mentioned above indicates the basic type to which each bone belongs.

Morphology. These observations suggest that there are two possible elements in the epipterice bone. The more common element corresponds to Type I and is at a more advanced stage in Type II. The less common element corresponds to Type III. Both elements present together corresponds to Types IV and V. The two elements may remain separate (14 pteria), but more commonly fuse (41 pteria).

If this hypothesis is correct, then the suture between double epipterice bones would be expected to run between the frontal and temporal bones (Type IV), or between the alisphenoid and temporal bones (Type V). Owing to the factors causing variation in this region other arrangements are possible, but the least probable is for the suture to run between parietal and alisphenoid bones.

Reference to drawings of all available multiple epipterice bones (fig. 2 m and n, o to z) gives actual figures as follows: frontal to temporal in 6 pteria, parietal to temporal in three, frontal to alisphenoid in three, alisphenoid to temporal in one, and alisphenoid to parietal in one.

Allowing, then, for the exuberant variability and for the doubling of one or both elements in some cases, this observation supports the hypothesis.

The epipterice bone articulating with only three others (Type I) is always contiguous with the parietal, temporal and alisphenoid and never with the frontal. The significance of this is not known, but it may be of morphological importance.

Combined types of pteria

Combination of Type II epipteric bone and frontal process was seen in three pteria, two right and one left (fig. 2 ab). The same combination was seen in one pterion, right, in which the frontal process did not reach the frontal bone (fig. 2 ac).

Combination of Type III epipteric bone and frontal process was seen in three pteria, one right and two left (fig. 2 ad). The same combination was seen in one pterion, right, in which the frontal process did not reach the frontal bone (fig. 2 ae).

When a fronto-temporal suture is present it is serrated, when the frontal process is "abortive" its margin is rounded.

Both elements of the epipteric bone are seen to occur with a frontal process of the temporal bone. This suggests that they are morphologically different, and that the frontal process is not an annexed epipteric bone.

Incidence and pairing

With the 4 types of pterion contact 16 combinations are possible, 4 bilaterally symmetrical with the same type on right and left sides, and 12 bilaterally asymmetrical with different types on right and left sides.

The findings (table 1, fig. 3) show that paired spheno-parietal contact is the most common arrangement (62.0%). Symmetry in the pairing is much more common than asymmetry (73.9% against 26.1%). Spheno-parietal contact also predominates in the asymmetrical series. The distribution of types of contact to right and left sides in the asymmetrical series is equal.

This suggests that symmetrical spheno-parietal contact is the mode, but when this fails contact may be epipteric bone(s), frontal process of temporal bone, or stellate, in that order of frequency.

It can be inferred that side (right or left) has no influence on the method of contact at the pterion.

Effect of sex and age. Data on skulls estimated to be male (185) and female (131) were recorded separately. Juveniles

TABLE 1

Incidence and pairing of types of pterion contact in the Australian aborigine

PAIRING OF TYPES OF CONTACT		NUMBER OF SKULLS	PER CENT
Right	Left		
Spheno-parietal	- Spheno-parietal	228	62.0
Epipteric bone	- Epipteric bone	31	8.4
Fronto-temporal	- Fronto-temporal	13	3.5
Stellate	- Stellate	0	0
Spheno-parietal	- Epipteric bone	31	8.4
Epipteric bone	- Spheno-parietal	31	8.4
Spheno-parietal	- Fronto-temporal	11	3.0
Fronto-temporal	- Spheno-parietal	7	1.9
Epipteric bone	- Fronto-temporal	6	1.6
Fronto-temporal	- Epipteric bone	5	1.4
Spheno-parietal	- Stellate	2	0.5
Stellate	- Spheno-parietal	1	0.3
Epipteric bone	- Stellate	0	0
Stellate	- Epipteric bone	0	0
Fronto-temporal	- Stellate	1	0.3
Stellate	- Fronto-temporal	1	0.3
Totals		368	100
Symmetrical pairing		272	73.9
Asymmetrical pairing		96	26.1

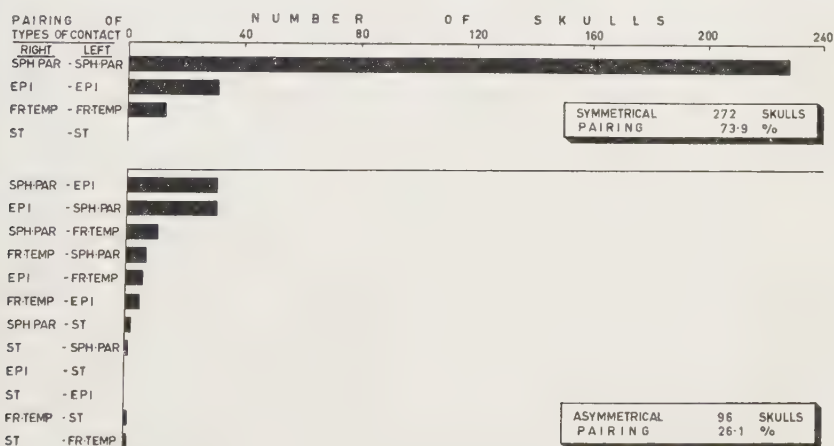


Fig. 3 Incidence and pairing of types of pterion contact.

TABLE 2

Pairing of types of Australian aboriginal pterion contact in male and female; in young, intermediate, and old skulls; and in the total series

TYPE OF CONTACT	SEX INCIDENCE		AGE INCIDENCE			TOTAL SERIES
	Males	Females	Young	Intermediate	Old	
Symmetrical pairing						
Sph-par	119 (64.3%)	75 (57.3%)	50 (59.5%)	125 (65.8%)	47 (57.3%)	238 (62.0%)
Sph-par						
Epi-	15 (8.0%)	11 (8.4%)	8 (9.5%)	12 (6.3%)	10 (12.2%)	31 (8.4%)
Epi						
Fr-temp	8 (4.3%)	5 (3.8%)	2 (2.4%)	9 (4.8%)	2 (2.4%)	13 (3.5%)
Fr-temp						
St-	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
St						
Asymmetrical pairing						
Sph-par	27 (14.5%)	24 (18.3%)	19 (22.6%)	27 (14.2%)	14 (17.2%)	62 (16.8%)
Epi						
Sph-par	7 (3.8%)	10 (7.6%)	4 (4.8%)	7 (3.7%)	5 (6.1%)	18 (4.9%)
Fr-temp						
Epi-	5 (2.7%)	5 (3.8%)	1 (1.2%)	7 (3.7%)	2 (2.4%)	11 (3.0%)
Fr-temp						
Sph-par	2 (1.2%)	1 (0.8%)	0 (0%)	1 (0.5%)	2 (2.4%)	3 (0.8%)
St						
Epi	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
St						
Fr-temp	2 (1.2%)	0 (0%)	0 (0%)	2 (1.0%)	0 (0%)	2 (0.6%)
St						
Totals	185 (100.0%)	131 (100.0%)	84 (100.0%)	190 (100.0%)	82 (100.0%)	368 (100.0%)

and adolescents were excluded from this sex-incidence part of the investigation. Data on young (84), intermediate (190), and old (82) skulls were also recorded separately. Juveniles, adolescents and those with Broca's Grade I attrition were classified as young, those with Grades II and III attrition as intermediate, and those with Grade IV attrition as old.

Pairing was recorded irrespective of side following the inference drawn above.

The findings (table 2) indicate the general trend to be the same in all groups as in the total series. It can be inferred that sex and age have no influence on the method of contact at the pterion.

Quantitative study of the pterion suture

The pterion suture is the suture between the alisphenoid and parietal or between the frontal and temporal depending on the type of contact. The 135 pteria with this suture complicated by epipteric bone(s) were excluded from this part of the investigation. The remaining 601 pteria show spheno-parietal, stellate, or fronto-temporal contact.

The pterion value is the length of the pterion suture. For convenience of measurement stellate contact was given a zero value, spheno-parietal contact a plus value, and fronto-temporal contact a minus value.

The results (table 3, fig. 4) show a curve of incidence which confirms the previous observations of preponderance of spheno-parietal contact. However, the curve is not the smooth one expected of normal variation, but has two unequal peaks towards which the items tend to cluster, with a trough between which the items tend to avoid.

Regarded as two separate curves the smaller left one is skewed to the right and has a mean corresponding to a fronto-temporal contact of 11.2 with a standard deviation of 4.2 mm; while the larger right one is skewed to the left and has a mean corresponding to a spheno-parietal contact of 6.5 with a standard deviation of 3.6 mm.

TABLE 3

Pterion value for 601 pteria in the Australian aborigine
(Pterion contact through epipteric bones excluded)

PTERION VALUE IN MILLIMETRES	NUMBER OF PTERIA
-22 and -21	1 (0.2%)
-20 to -18	4 (0.6%)
-17 to -15	5 (0.8%)
-14 to -12	8 (1.3%)
-11 to -9	15 (2.5%)
-8 to -6	14 (2.3%)
-5 to -3	2 (0.3%)
-2 to 0	13 (2.2%)
1 to 3	96 (16.0%)
4 to 6	199 (33.3%)
7 to 9	139 (23.3%)
10 to 12	75 (12.3%)
13 to 15	24 (4.0%)
16 to 18	4 (0.6%)
19	2 (0.3%)
Total	601 (100.0%)

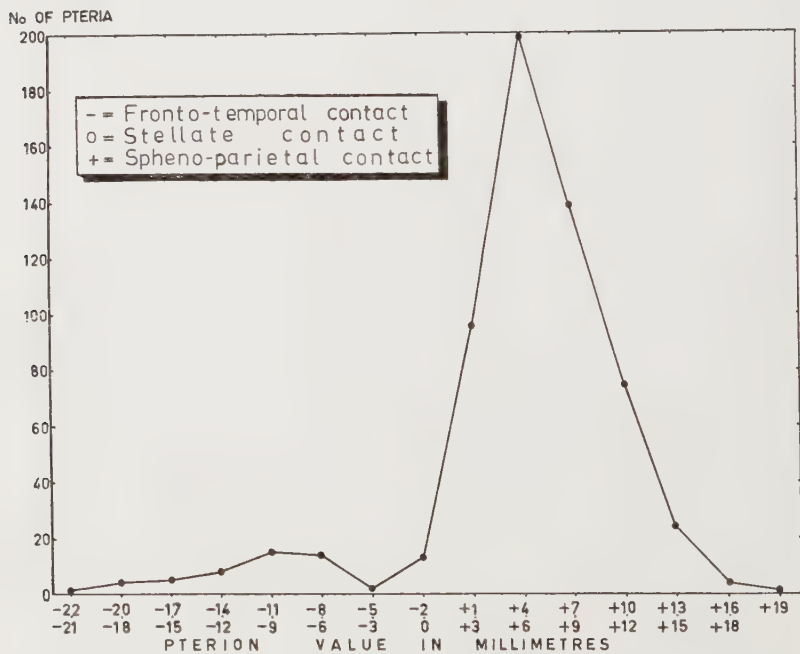


Fig. 4 Frequency distribution curve of length of pterion suture.

There are two possible explanations of this bi-modality. One is that the material being examined is not homogeneous. The other is that some factor is present which militates against fronto-temporal contact in the region of 3 to 5 mm, but allows a greater or lesser fronto-temporal contact.

Correlative observations

Skull features claimed to be associated with one or other type of pterion contact are head length, "stenocrotaphy," degree of cranial flexion, and the bone formation in the anterior cranial fossa.

"Stenocrotaphy" has been defined as a bi-pteric, post-orbital, or post-frontal narrowing of the skull. Owing to the difficulty of defining a fixed point of measurement for the various types of pterion, it was decided to measure the skull width at the point closest to its fellow on the fronto-alisphenoid suture, and to call this the post-orbital breadth.

The degree of cranial flexion is difficult to measure in unsplit skulls. It was felt, however, that the angle nasion — top of dorsum sellae — basion would be sufficient to investigate possible correlation. This was calculated from the measurements of the three sides of the triangle completed by these points, and called the basi-cranial angle.

Data for the presence or absence of an ethmoidal spine of the sphenoid were obtained from a previous investigation (Murphy, '55).

To make any possible correlation more clear-cut, skulls with asymmetrical pairing were excluded from this part of the investigation. Cranial index, post-orbital breadth, basi-cranial angle, and presence/absence ethmoidal spine were plotted against the various types of bilateral pterion contact.

The results (table 4) indicate no significant correlation.

The figures for presence/absence of ethmoidal spine of sphenoid with the various degrees of spheno-parietal contact are relatively constant. There is a divergence in different

directions with epipteric bone(s) and fronto-temporal contact. It seemed, therefore, worthwhile to make a percentage bar chart (fig. 5).

TABLE 4
Correlation of type of bi-lateral pterion contact with cranial index, post-orbital breadth, basi-cranial angle, and presence or absence of ethmoidal spine of the sphenoid

TYPE OF BILATERAL PTERION CONTACT	CRANIAL INDEX		POST-ORBITAL BREADTH (millimetres)		BASI-CRANIAL ANGLE (degrees)		ETHMOIDAL SPINE OF SPHENOID	
	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.	Present	Absent
Spheno-parietal								
-narrow	70.0	2.7	85.9	4.1	115.6	5.2	17	7
-medium	70.7	3.2	85.5	4.4	116.6	6.6	28	12
-wide	70.6	3.3	86.9	3.7	114.9	6.6	24	8
Fronto-temporal	72.1	2.1	86.2	4.6	116.4	3.7	10	0
Epipteric bone (s)	70.0	3.5	85.3	3.7	118.2	6.9	10	8
Total series	70.5	3.1	85.9	4.1	116.3	6.2	89	35

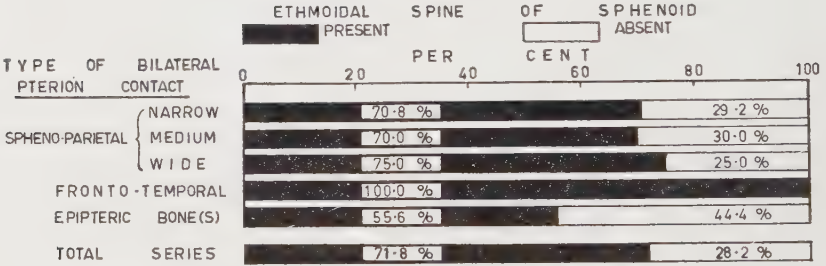


Fig. 5 Percentage bar chart showing association between ethmoidal spine of sphenoid and the various types of pterion contact.

DISCUSSION

Relevant aspects of skull growth

Mechanical factors. The type of pterion is determined by the degree of relative growth of the pteric bones, forming varying sutural patterns. Kokott ('33) postulates that these sutures represent lines of condensation in the dura mater

which, at an earlier stage, control the growth of the membranous capsule, as the bracing ropes of a parachute control the envelope as it opens. The pterion is a key region where these bracing ropes are anchored to the phylogenetically older cartilage bone base. Troitsky's ('32) work, confirmed by Moss ('54), indicates that these are non-osteogenic strips, over which bone does not grow.

Genetic factors. Abbie ('52) shows that the human skull is a "physical mosaic" of independently-inherited characteristics. The design of the mosaic for each ethnic group is determined by its own genetic pool.

Pteric anomalies, then, must be considered both from mechanical and genetic viewpoints.

The pteric bones and the pterion suture

De Beer ('37) discusses differences in bone contacts in the orbito-temporal region and states (p. 483) that these "can be taken as natural experiments of variation in the extent of the bones," and (p. 484) that these "are of no fundamental importance."

Observations on the pteric bones in the present study conform with the conception of normal variability except the cases illustrated in figure 1, m, n and o. The quantitative study of the pterion suture (fig. 4) shows two curves with a trough between. The right curve contains a few fronto-temporal contacts which merge into stellate and an increasing degree of spheno-parietal contact in the smooth manner of normal variation. The smaller left curve is formed by the type of case with a definite projecting fronto-temporal process and has a curve of normal variation of its own. Thus there are two kinds of fronto-temporal contact. This confirms the observations of older workers who distinguished between "mediate" and "immediate" contact.

Both curves in figure 4 are skewed towards the trough. A mechanical explanation would be that, as the degree of variation moves further towards a wide fronto-temporal

contact, it conflicts with and is cut into by a non-osteogenic strip. The part of the squamous forming the contact then takes on the appearance of a projecting process, which "fans out" to make an increasing fronto-temporal contact.

A genetic explanation would be that the right curve fronto-temporal process (figs. 1 k and l) is an extreme degree of normal variability, but that the left curve fronto-temporal process (figs. 1 m, n and o) is as definite an anatomical attribute as a supra-condylar process or a supernumerary tooth, and is produced by a gene complex whose frequency varies in different ethnic groups.

The earlier workers, reflecting the biological thought of the time on evolution as a continuous process of blending inheritance, tried to decide the relative zoological position of the various human races on the incidence of fronto-temporal contact at the pterion. They suggested that the "inferior" races were a gradation between the non-human primates and the "superior" races — to which the investigator invariably belonged.

In the present study the percentage of skulls showing either bilateral or unilateral fronto-temporal contact is 12.0% in 368 Australian aboriginal skulls. This compares with other records of Australian skulls as follows; 10.6% in 103 (Collins, '26), 10.8% in 231 (Ashley-Montagu, '33) and 11.9% in 766 (Fenner, '39).

Ashley-Montagu ('33) cites the summated findings of various authors for the incidence of fronto-temporal contact in European and anthropoid skulls as follows: European 1.9% in 26,240; Gorilla 98.7% in 376; Chimpanzee 89.8% in 385; Orang-utan 29.0% in 578; and Gibbon 19.4% in 209.

The epipteric bones

Ashley-Montagu ('33) summarizes the theories of origin of epipteric bones as detachment from the primitive cartilaginous blade proceeding laterally from the anterior clinoid process, an independent center of ossification which may

represent inter-temporal or post-frontal bone, or detachment from the angles of adjoining bones.

The present study shows that epipteric bones, in spite of their great variation, do conform to a more regular pattern than has hitherto been described. This tends to rule out the sutural bone theory and supports the independent center of ossification one, the frequency of the gene complex involved varying in different ethnic groups. Mechanically, however, a "forking" of the bracing rope near its chondrocranial anchor would also make a plausible explanation.

Whether or not the fronto-temporal process is an annexed epipteric bone has long been a controversial question. Inkster in Cunningham ('51, p. 238) states that it is. Combined types of pteria (figs. 2 ab, ac, ad, ae) showing both factors together were first noted in 1898. The possible opposing association between the two factors and the ethmoid spine of the sphenoid (fig. 5) also suggests that they are morphologically different.

In the present study the percentage of skulls showing an epipteric bone on one or both sides is 28.3% in 368 Australian aboriginal skulls. This compares with other records of Australian skulls as follows; 7.3% in 231 (Ashley-Montagu, '33), and 24% in 822 (Fenner, '39). The discrepancy between Ashley-Montagu's and the other figures is puzzling.

Summated findings from Ashley-Montagu ('33) for the incidence of epipteric bones are as follows: European 12.7% in 3,451; Gorilla 0.7% in 285; Chimpanzee 0.4% in 240; Orangutan nil in 146; and Gibbon 1.2% in 83.

Thus the position of the Australian between the European and the non-human primates on the basis of the incidence of fronto-temporal contact, becomes reversed, with the European in the intermediate position, on the basis of the incidence of epipteric bones, an equally valid morphological criterion.

Correlative observations

The post-orbital narrowing which the older writers called "stenocrotaphy" has long been stated to be a factor in leading

to fronto-temporal contact. So strong was this belief that the word came to be synonymous with fronto-temporal or a narrow speno-parietal contact, and it was common to read of "stenocrotaphy" of 3 mm meaning speno-parietal contact of this value. The present study shows no correlation.

Weidenreich ('41) notes the position of the pterion at the transverse axis of cranial flexion and contends that this has an influence on the type of pterion. If this is correct there should be a correlation between the angle of cranial flexion (basi-cranial angle) and the length of the pterion suture. The present study does not bear this out.

Wood Jones ('28) includes the pterion with the speno-ethmoidal articulation in the anterior cranial fossa as being a "hall mark of mankind." Although the present study (fig. 5) suggests that fronto-temporal contact is associated with the ethmoidal spine of the sphenoid, and epipteric bones are commoner in its absence, insufficient material prevents statistical significance being established.

CONCLUSION

The variations noted for the pterion in the present investigation, and for the speno-ethmoidal articulation in the anterior cranial fossa in a previous investigation (Murphy, '55), seem to be greater within one ethnic group than variation in neighboring regions. As Wood Jones ('28) points out, these regions show great differences in the arrangement in the various primate species. It is probable that any region which shows great species variation, will also show a correspondingly great ethnic variation between human groups, and even great individual variation among individuals in an ethnic group. Thus the pterion and the speno-ethmoidal articulation in the anterior cranial fossa may be regarded as regions in which phylogenetic stability has not yet been achieved.

SUMMARY

1. A record is presented of the types and incidence of variations at the pterion of 368 Australian aboriginal skulls.

2. Spheno-parietal contact is by far the most common arrangement (539 pteria), followed by epipteric bone(s) (135), fronto-temporal (57) and stellate (5). There is a bias towards symmetry in the pairing (73.9% against 26.1%). Age, sex, and side (right or left) have no influence on the type of contact. Percentage of skulls with paired spheno-parietal contact is 62%, with epipteric bone contact on one or both sides 28.3%, and with fronto-temporal contact on one or both sides 12%.

3. Epipteric bones show great variation, but can be classified into 5 basic types. These appear to be formed by one or both of two morphological elements. A fronto-temporal process effecting fronto-temporal contact was present with epipteric bones in 6 pteria.

4. Type of pterion contact could not be correlated with cranial index, post-orbital narrowing of the skulls, the basicranial angle, nor with the arrangement of the bones in the anterior cranial fossa.

5. Possible mechanical and genetic factors in the literature are reviewed.

ACKNOWLEDGMENTS

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PHYSICAL GROWTH OF THE RHESUS MONKEY (*MACACA MULATTA*)¹

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THIRTEEN FIGURES

Information on growth and development of the common laboratory monkey, *Macaca mulatta*, has been available only for a few individual animals. The amassing of such data requires colonies of monkeys wherein conception can be dated, duration of the individual pregnancy determined, and where infants can be observed continuously from birth. Such studies may require decades when the animal has a six months gestation period and a maturation time of three years. Observations on the normal animal and experiments that extend over such prolonged periods are unusually difficult to control because modified conditions, known or unknown, may be introduced. A well regulated and successful colony makes use of changing methods in the treatment of acute and chronic diseases which often decimated the earlier established monkey

¹ A special Grant (C-2304) was made in 1951 by the United States Public Health Service for the organization and analysis of the normal growth data on the rhesus monkey which had accumulated in this laboratory. Unlike earlier colonies these monkeys were housed entirely within the laboratory and at that time 6 generations were represented.

Mr. Joseph Negri has been responsible for the welfare of the monkey colony since the beginning of the breeding program as well as for the meticulous keeping of the records upon which this study and others arising from the colony explicitly depend. Mr. Negri's contribution of 20 years is thus commensurate with the project as a whole and is admired by all those who have had occasion to consult his records.

colonies. Diets with supplements capable of supporting repeated pregnancy and lactation in the mothers and optimal growth in the young must be kept up to date and the diets are as subject to modification as are human diets under conditions of economic stress or warfare. It may become possible or expedient to raise some infants away from their mothers. Over a sufficiently long period, also, the effects of inbreeding and selection may become manifest. The most extensive previous study of macaque growth, that of Schultz (in Hartman and Straus, '33), was made on a beginning group of some twenty animals born in the Carnegie colony.

Monkeys were first maintained in the Department of Obstetrics and Gynecology, Yale University School of Medicine in 1931.² At that time the main problems were the control of tuberculosis, pernicious diarrheas and pneumonia. These infectious diseases were controlled at first by nursing care with rigid selection and elimination and later by sulfa drugs and the antibiotics.

In 1935³ investigations of certain problems of pregnancy led to the establishment of a self-sustaining colony. Several aspects of the long-term care and study of these monkeys: housing, caging, feeding, mating, and care of infants have been described (van Wageningen, '45a, '45b and '50). In the 23 years since the colony originated, and 19 years since the beginning of breeding, there have been 354 pregnancies, three of them twin pregnancies. The first monkeys are no longer living, but several 18-year-olds and one 20-year-old monkey remain ('55).

The colony has continued through these years under the care and supervision of the same two people (J. Negri and G. v.

² Stimulated by the work of Drs. George Corner, Edgar Allen and Carl Hartman who during the previous 10 years added experimental work using the rhesus monkey to supplement their studies of the menstrual cycles of man, the writer (G.v.W.), together with Dr. Sophie Aberle, acquired the first rhesus monkey from a local pet shop to begin this colony.

³ Professor Arthur H. Morse unreservedly threw the larger part of the research resources of his Department to the support of this work in which he continued an active and generous interest until his retirement in 1947.

W.). This has assured a uniformity in records during the period of gradual accumulation of measurements on those normal animals which were maintained in the experimental laboratory.

MATERIAL AND METHOD

The basic data gathered over a period of some 20 years on the growth of monkeys in the Yale Obstetrical Colony from birth until approximately the 7th year of life will be presented. Reasonably large groups of male and female animals have been available for this purpose. Certain aspects of interest to the first few months of life are emphasized. During the period preceding and during the sexual maturation phase, especially in the female, the growth correlates will be described more particularly.

Data of this type are obtained by routine daily, weekly or monthly observations according to age and specific records. They are often superimposed on the programming of other studies of more immediate interest; some of which may, in themselves, have a direct and important bearing on growth. Thus the time of onset of sexual maturation must be considered in the interpretation of a growth curve. Studies have been reported from this same colony on the development of the testis (van Wagenen and Simpson, '54), the eruption of the deciduous dentition (Hurme and van Wagenen, '53), and on the acceleration of growth by the use of testosterone propionate (van Wagenen, '47 and '49). Preliminary papers have appeared on the age at menarche (van Wagenen, '52), on the care of, and size of, the newborn (van Wagenen, '54; Gavan and van Wagenen, '55) and growth curves of some infants born in this colony have been presented (Pickering, Smyth, van Wagenen and Fisher, '53; Lusted, Pickering, Fisher and Smyth, '53; Crane, Pickering, van Wagenen and Smyth, '54). Studies on the development of the ovary, on the eruption of the permanent dentition, and on the maturation of the skeleton are being prepared. Most of the animals were ob-

served repeatedly from birth, and measured at frequent intervals. Babies up to 4 to 6 months were weighed daily and measured weekly; from 6 months to a year they were weighed and measured weekly, and, after one year, monthly, unless circumstances suggested more frequent observation. Body length (crown-rump) measurements were taken from vertex to ischial callosities with the animal lying on its side, using the Hrdlicka large sliding callipers. After attaining one year of age, certain animals were placed on experiments and the numbers available for normal growth studies progressively decreased. However, 68% of the females were still available at the end of the third year, when maturation had universally occurred. For estimation of the population mean weight and mean sitting height the data were treated as purely cross sectional since it was felt that this would be adequate for deciding the status of a given animal without introducing the complexity of the longitudinal element. For construction of the charts and graphs of height and weight increments, advantage was taken of the longitudinal element by computing increments from month to month for each individual animal (cf. Tanner, '51). To avoid undue duplication, the mean increment curves only will be presented here.

The female macaque

Body weight during infancy (to 4 months of age). Seventy-two animals were initially available for this study. The nursing infants usually lost weight during the post-natal period. The rates of early growth were determined by noting the time required to regain the birth weight and the time required to double the birth weight. Most animals regain their birth weight within the first two weeks; a few individuals not till the third or fourth week. The birth weight doubled in 92 ± 21 days (range 53 to 150 days) (table 1). Although the lighter animals tended to double their birth weights earlier, this difference was not significant. The growth pat-

tern of nurslings was compared with that of animals fed by formula during the first 12 weeks of life. Weight curves, computed as absolute weights, week by week, and also as grams per kilogram per day were analyzed for 40 of the former and 34 of the latter (fig. 9; table 2). Formula-fed animals achieved

TABLE 1

Female monkeys: Times at which the birth weight was regained and doubled in female macaques

NO. OF ANIMALS	MEAN BIRTH WEIGHT	TIME AT WHICH BIRTH WEIGHT WAS REGAINED	TIME AT WHICH BIRTH WEIGHT WAS DOUBLED
	<i>gm</i>	<i>days</i>	<i>days</i>
70-72 (a)	467	7.1 ± 6.5 *	92 ± 21 *
		(S.E. _m = 0.7)	(S.E. _m = 2.5)

* Standard deviation.

(a) 70 animals were used for the first determination, 72 for the second.

TABLE 2

Female monkeys: Comparison of the times of regaining and of doubling the birth weight in nursing and non-nursling (formula-fed) female macaques

	NO. OF ANIMALS	MEAN WEIGHT AT BIRTH	TIME IN WHICH BIRTH WEIGHT WAS REGAINED	TIME IN WHICH BIRTH WEIGHT WAS DOUBLED	LINEAR GROWTH PERIOD	WEEKLY GAIN IN WEIGHT
		<i>gm</i>	<i>days</i>	<i>days</i>	<i>weeks</i>	<i>gm</i>
Nursling	40-38	460	5.6 ± 6.3 (a)	97 ± 19 (b)	3 to 12	35
			(S.E. _m = 1.0)	(S.E. _m = 3.0)		
Formula-fed	34-32	473	8.2 ± 5.6 (a)	82 ± 16 (b)	1 to 12	45.5
			(S.E. _m = 1.0)	(S.E. _m = 2.8)		

(a) Difference not significant.

(b) Difference significant, $P < .01$.

straight line growth by the end of the first week, and made thereafter a weekly gain of 45 grams. Breast-fed animals did not reach straight line growth till the third week, and then showed weekly increments of 35 gm. In both groups, the birth weight was regained at times that did not differ significantly; however, the time required to double their birth

weights was significantly accelerated in the formula-fed animals. In general, therefore, the growth rate of young female monkeys was increased by laboratory-controlled formula feeding.

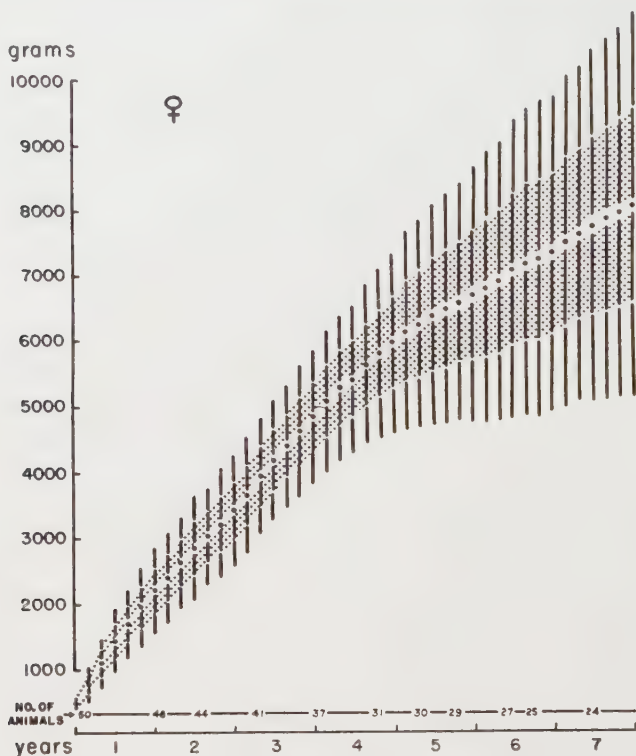


Fig. 1 Body weight of female macaques in relation to chronological age. Included are areas showing one standard deviation of the mean (68.3%) and two standard deviations (95.4%).

Body weight data: birth to 7 years. Fifty female monkeys born into the colony between 1930 and 1952 were used. Their average weight at birth was 465 ± 70 gm, range 325 to 640 gm. The number of animals available during successive years of observation were: first year, 50; second year, 46-43; third year, 43-34; 4th year, 37-31; 5th year, 31-28; 6th year, 28-25; 7th year, 25-21. (The number given first was the number starting the year; the second number, those present at

the end of the year). Body weight increase with chronological age is represented as a mean curve with one and two standard deviations (fig. 1) and tabulated (table 3). Smoothing tends to obscure some details of the growth to 4 years of age which

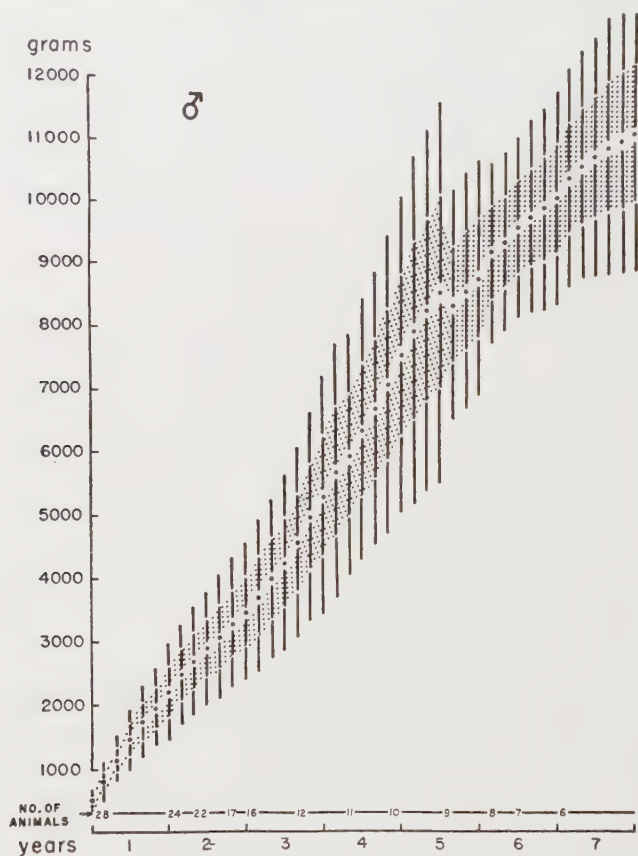


Fig. 2 Body weight of male maeques in relation to chronological age. Means, with one (68.3%) and two (95.4%) standard deviations.

will be dealt with presently. After 5 years, the growth curve flattens, and the overall variability becomes quite large due to such factors as obesity, periodic pregnancy and occasional illness in animals comprising the group.

The increments of body weight (fig. 5) were greatest, 140 to 170 gm per month, during the first 7 months, and diminished

to 90 to 100 gm per month at $1\frac{1}{12}$ to $1\frac{10}{12}$ years. (Throughout this paper, months are expressed as fractions of a year.) This temporary quiescent phase is followed by a growth spurt, reaching 140 gm per month at $2\frac{1}{12}$ years. Thereafter increments fall off gradually to 60 to 70 gm per month at $4\frac{6}{12}$ years.

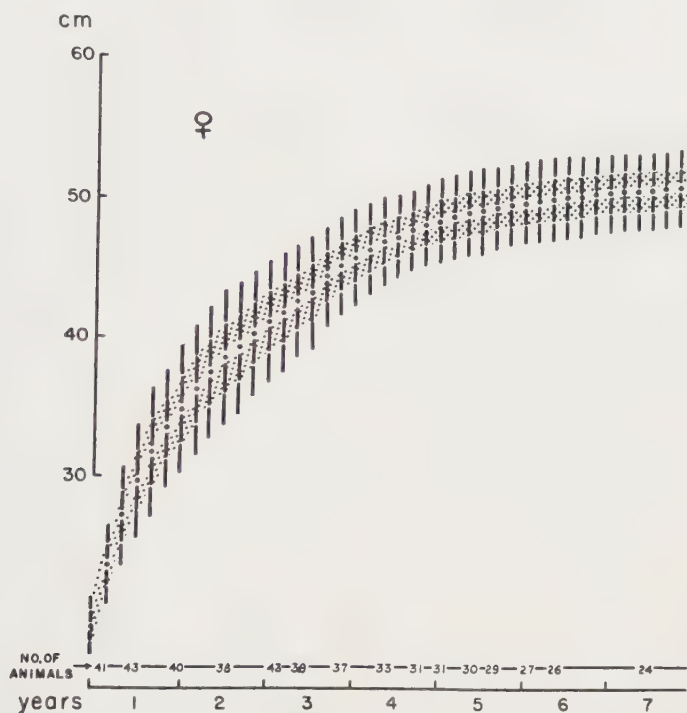


Fig. 3 Crown-rump length of female macaques in relation to chronological age. Means, with one and two standard deviations.

It is instructive to examine the weight record for an individual female followed for 10 years (fig. 10). This monkey, Mm 272 was born on March, 1935 and reached menarche at $1\frac{6}{12}$ years with an isolated bleeding period. Regular menstrual periods began at the end of this second year of life. Growth was interrupted temporarily and then showed a distinct acceleration with the establishment of regular menstrual cycles. Subsequently this animal became repeatedly pregnant,

and showed the expected periodic weight fluctuations superimposed on a gradually rising weight curve.

Comparison of weight increment curves of early and late maturing female macaques. To attempt to correlate growth and sexual maturation in the female monkey, a group of 10 animals that reached menarche at the earliest ages was compared with a group of 10, the latest to reach menarche.

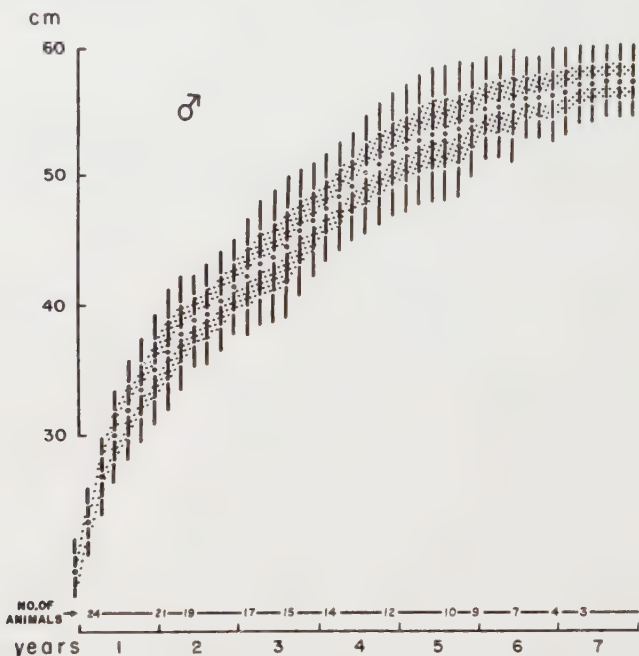


Fig. 4 Crown-rump length of male macaques in relation to chronological age. Means, with one and two standard deviations.

The former group showed first menses at $1\frac{8}{12}$ years ± 43 days (range $1\frac{5}{12}$ to $1\frac{11}{12}$ years); the latter at $2\frac{5}{12}$ years ± 59 days (range $2\frac{1}{12}$ to $2\frac{11}{12}$ years). The average birth weight of the first group was 461 gm (range 321 to 570 gm); of the latter, 444 gm (range 360 to 565 gm). The early maturing group showed an initial rapid rate of growth subsiding at $1\frac{1}{12}$ years, followed immediately by a spurt reaching a maximum at $2\frac{8}{12}$ years (fig. 7). The beginning of the

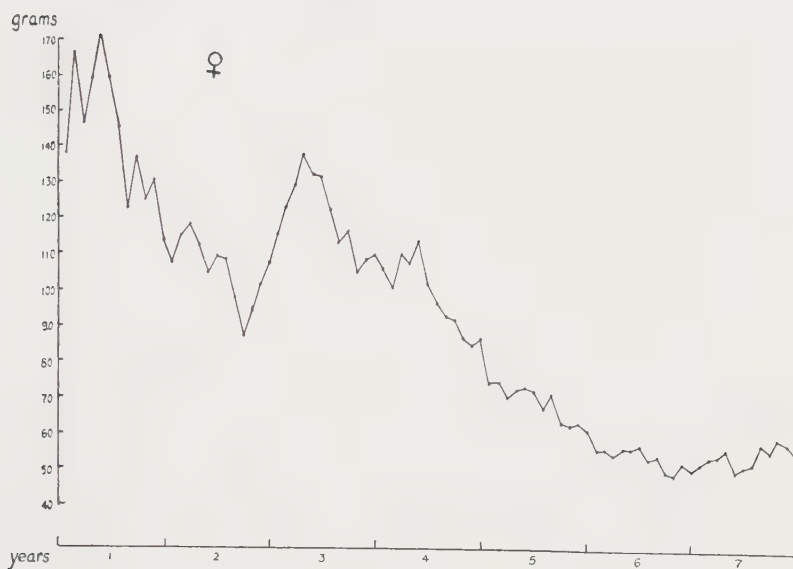


Fig. 5 Weight increment curve for female macaques. Numbers of animals as in figure 1.

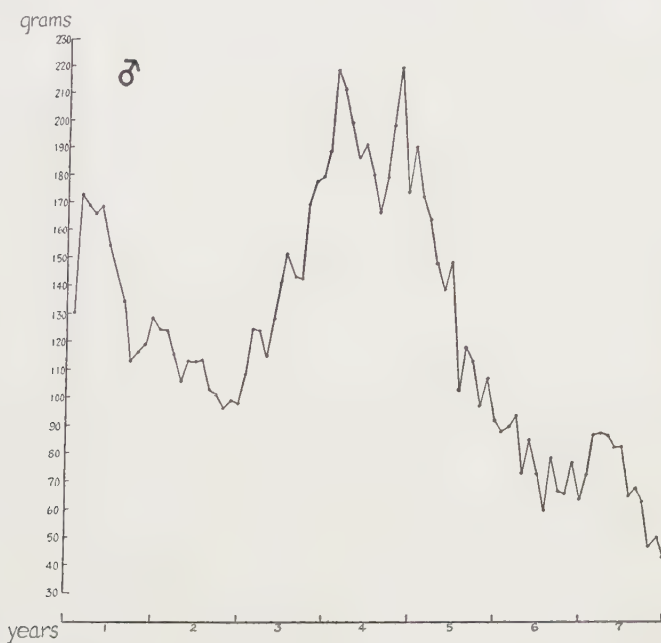


Fig. 6 Weight increment curve for male macaques. Numbers of animals as in figure 2.

“adolescence” growth spurt thus coincides closely with the mean date of menarche. The late maturing group had at first a growth curve running consistently below that for the early group. The adolescence growth spurt, coming at the end of the second year, exceeded that of the early maturing monkeys in extent, and was decidedly prolonged, reaching a maximum at 3 to 3 $\frac{1}{2}$ years. Curves plotted for each of these 20 animals

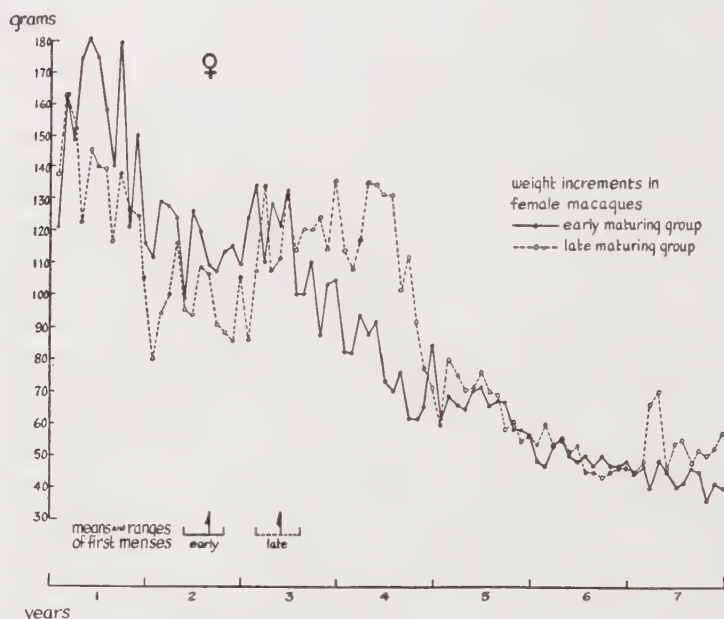


Fig. 7 Weight increment curves for 10 early and 10 late maturing female macaques. The means and ranges of the first menstrual times are below the curves.

showed considerable individual variation in the form of the curves, with, on the whole, a fair degree of association of the adolescence growth spurt with the onset of menarche.

Body length (crown-rump). Sitting height increase with age is shown as a mean curve with one and two standard deviations (fig. 3) and tabulated (table 4). The monthly increments of sitting height were greatest during the first year (fig. 8). There is a definite, but not striking, effect correspond-

TABLE 4

Crown-rump length, in centimeters, of female macaques in relation to chronological age taken month by month. Numbers of animals at successive times are indicated, with mean lengths and standard deviations

YEAR	BIRTH	MONTHS											
		1	2	3	4	5	6	7	8	9	10	11	12
0	NO. OF ANIMALS	37—41				42—43							
	Mean	19.4	21.9	23.8	25.5	27.3	28.6	29.8	30.8	31.8	32.7	33.5	34.2
	Std. dev.	1.0	1.4	1.4	1.6	1.7	1.9	2.0	2.5	2.3	2.3	2.0	2.5
1	No.	40		39				38	37				
	Mean	35.6	36.3	36.9	37.5	38.1	38.6	39.0	39.3	39.7	40.3	40.7	41.2
	S.D.	2.4	2.4	2.3	2.3	2.3	2.4	2.4	2.3	2.2	2.1	2.1	2.1
2	No.	40—43		42		39			38			37	
	Mean	41.2	41.8	42.3	42.7	43.0	43.3	43.8	44.5	44.8	45.2	45.5	45.8
	S.D.	2.1	2.1	2.0	2.0	2.1	2.1	2.1	1.7	1.7	1.7	1.7	1.7
3	No.					33		32			31		30—
	Mean	46.1	46.4	46.7	47.0	47.1	47.3	47.6	47.8	48.0	48.2	48.3	48.5
	S.D.	1.7	1.6	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5
4	No.	31—				30			29		28		
	Mean	48.7	48.8	49.0	49.1	49.2	49.3	49.4	49.5	49.6	49.7	49.8	49.9
	S.D.	1.5	1.5	1.5	1.4	1.5	1.5	1.4	1.4	1.2	1.4	1.4	1.5
5	No.	27—				26	25						
	Mean	50.1	50.1	50.2	50.2	50.3	50.3	50.4	50.4	50.5	50.6	50.7	50.7
	S.D.	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.3	1.2	1.4
6	No.					24	23	22	21				
	Mean	50.7	50.8	50.8	50.8	50.8	50.9	51.0	51.1	51.1	51.2	51.2	51.2
	S.D.	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3

ing to the weight increment augmentation occurring at the time when sexual maturity is being achieved, but difficult to delimit with any exactness. It is a smaller and briefer effect in the female than that seen in the male (also shown in fig. 8). The sitting height of course fails to include the long bones which confer the principal increment in height in the human adolescent.

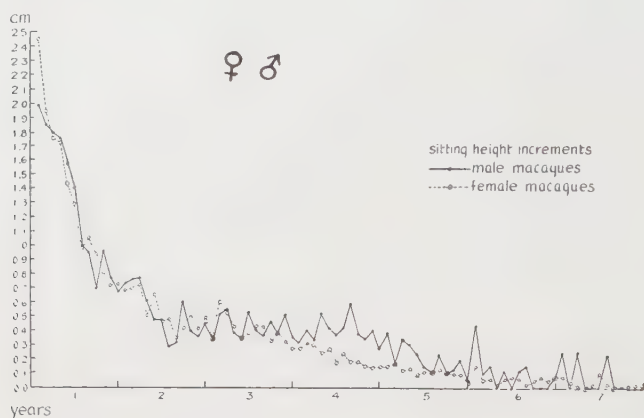


Fig. 8 Crown-rump length increments for male and female macaques. Numbers of animals as in figures 4 and 3 respectively.

The male macaque

Body weight during infancy (to 4 months). Eighty five animals were initially available (table 5). Birth weights for most animals were regained within the first two weeks, and were doubled at 90 days (range 50 to 140 days). Doubling time seemed to bear no relation to the birth weight.

A comparison of 26 nursling and 34 formula-fed male babies showed the same general trends (table 6, fig. 11) as did the females. The weight curve of formula-fed animals became a straight line at the end of the first week, as compared with three weeks for nurslings, and showed weekly gains of 48 gm, against 41 for nurslings. Neither the times of regaining nor doubling of the birth weights differed significantly for the two

groups, although the trend was toward an earlier doubling time in formula-fed animals.

Body weight: birth to 7 years. Twenty-eight male animals born into the colony between 1930 and 1950 were used. During successive years of study, their numbers were: 1st year,

TABLE 5

Male monkeys: Times at which the birth weight was regained and doubled in male macaques

NO. OF ANIMALS	MEAN BIRTH WEIGHT	TIME AT WHICH BIRTH WEIGHT WAS REGAINED	TIME AT WHICH BIRTH WEIGHT WAS DOUBLED
	<i>gm</i>	<i>days</i>	<i>days</i>
85	481	6.9 ± 6.7 *	90 ± 21 *
		(S.E. _m = 0.7)	(S.E. _m = 2.7)

* Standard deviation.

TABLE 6

Male monkeys: Comparison of the times of regaining and of doubling the birth weight in nursing and non-nursling (formula-fed) macaques

	NO. OF ANIMALS	MEAN WEIGHT AT BIRTH	TIME IN WHICH BIRTH WEIGHT WAS REGAINED	TIME IN WHICH BIRTH WEIGHT WAS DOUBLED	LINEAR GROWTH PERIOD	WEEKLY GAIN IN WEIGHT
		<i>gm</i>	<i>days</i>	<i>days</i>	<i>weeks</i>	<i>gm</i>
Nursling	26	481	6.7 ± 6.3 (a)	94 ± 29 (b)	3 to 12	41
			(S.E. _m = 1.2)	(S.E. _m = 5.7)		
Formula-fed	34-29 (c)	504	8.3 ± 7.9 (a)	82 ± 16 (b)	1 to 12	47.7
			(S.E. _m = 1.4)	(S.E. _m = 3.0)		

(a) Difference not significant.

(b) Difference not significant.

(c) i.e., number present initially was 34, later 29.

28; 2nd year, 24-17; 3rd year, 16-12; 4th year, 12-10; 5th year, 10-9; 6th year, 9-7; 7th year, 6. The average weight at birth was 490 ± 60 gm (range, 390 to 670 gm). Body weight increase with chronological age is represented as a mean curve with one and two standard deviations (fig. 2) and tabu-

lated (table 7). There is a rather distinct break in the composite growth curve at $2\frac{1}{12}$ years, representing the adolescence growth spurt. The apparent break at $4\frac{1}{12}$ years is an artefact caused by the removal from the group at this point of a single animal weighing 12 kg. In general the male

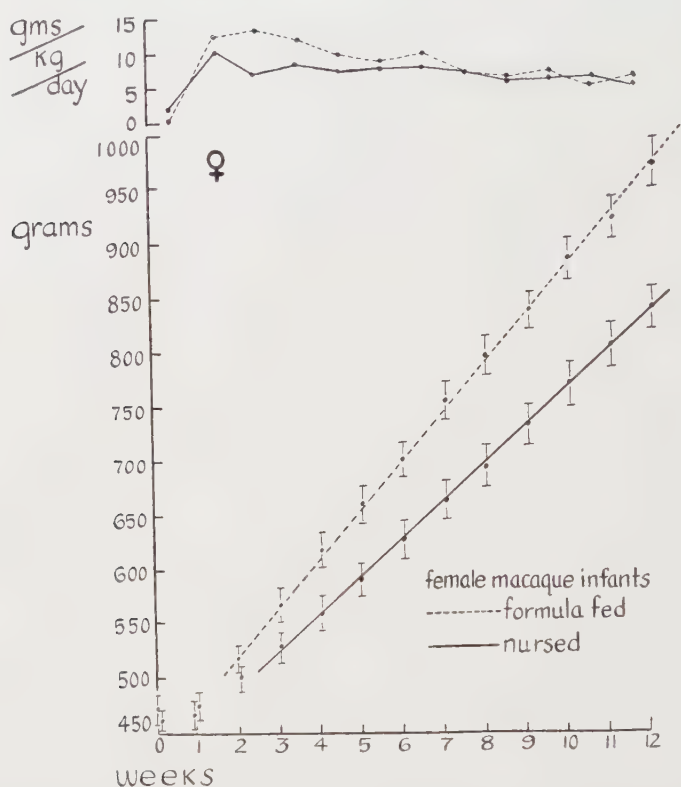


Fig. 9 Growth of nursing and formula-fed macaque infants during the first 12 weeks of life. Means and standard errors of the mean are indicated.

weight curve surpasses that of female, and shows no indication of plateauing through the 6th and 7th years.

The initial increments of weight are high, 170 gm per month (fig. 6), diminishing to 100 gm per month towards the end of the second year. Shortly thereafter a massive growth spurt begins, reaching a peak of 220 gm around $3\frac{1}{12}$ to $3\frac{11}{12}$

TABLE 7

Body weight in grams of male macaques in relation to chronological age taken month by month. Numbers of animals at successive times are indicated, with mean weights and standard deviations

YEAR	BIRTH	MONTHS											
		1	2	3	4	5	6	7	8	9	10	11	12
0	28												
	NO. OF ANIMALS												
	Mean	490	790	960	1125	1295	1450	1590	1725	1840	1950	2070	2195
	Std. dev.	60	120	145	165	195	235	265	295	305	315	345	375
1	24												
	No.	2335	2460	2575	2680	2770	2880	2965	3060	3160	3255	3355	3450
	Mean	395	415	425	430	425	445	435	480	485	505	510	525
	S.D.	16											
2	16												
	No.	3560	3685	3810	3970	4085	4225	4400	4545	4760	4930	5090	5270
	Mean	555	590	615	630	675	700	750	770	785	820	865	920
	S.D.	5460	5675	5890	5930	6125	6315	6495	6665	6840	7040	7345	7520
3	11												
	No.	975	1000	1020	950	985	1025	1050	1095	1160	1180	1255	1295
	Mean												
	S.D.												
4	9												
	No.	7710	7880	8055	8205	8340	8490	8180	8295	8420	8505	8610	8705
	Mean	1320	1375	1405	1435	1470	1500	885	890	915	920	940	940
	S.D.												
5	8												
	No.	8800	9120	9215	9285	9370	9525	9585	9665	9745	9815	9890	9970
	Mean	920	695	695	690	685	700	720	745	770	795	820	855
	S.D.												
6	6												
	No.	10200	10290	10380	10465	10550	10630	10700	10765	10830	10875	10925	10970
	Mean	825	850	880	905	935	965	985	1010	1040	1050	1045	1090
	S.D.												

years (no significance is attached to the dip in the curve between these times). Thereafter increments fall to 60 to 80 gm per month at $5\frac{1}{2}$ to 6 years. This growth spurt surpasses that of the female in extent and duration, and may be at-

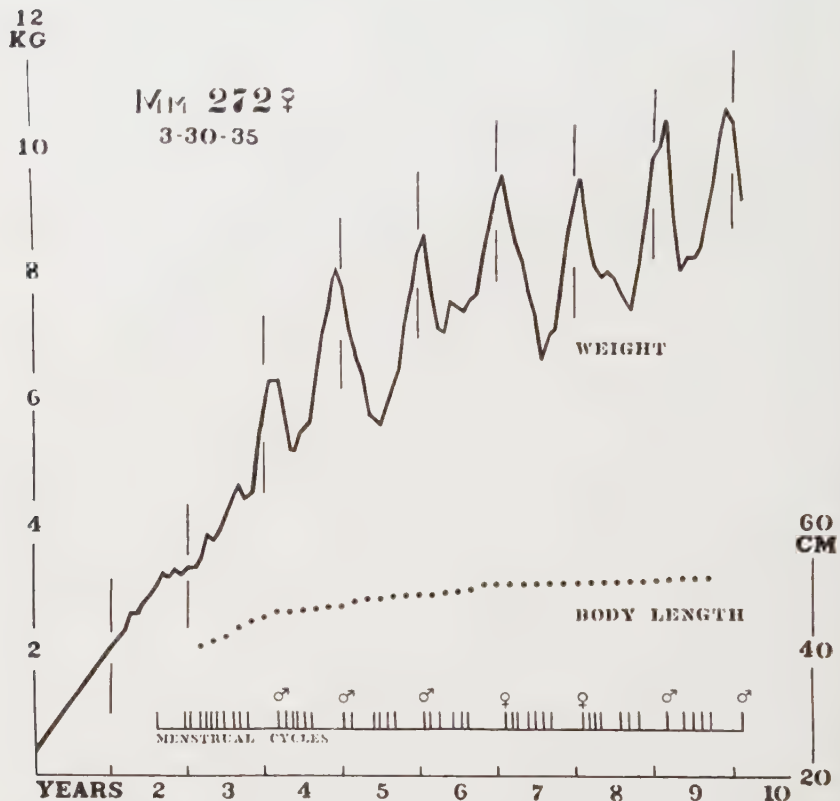


Fig. 10 Chart of growth and reproductive performance of a typical female macaque during a 10 year period. Body weight, sitting height and menstrual history are shown. Infants, male or female, were born at the times indicated by appropriate symbols.

tributed to the marked anabolic effect of the male sex hormone. Somatic growth has been repeatedly augmented experimentally in animals receiving testosterone propionate, including the macaque (van Wagenen, '47 and '49). The time of sexual maturation in the male is difficult of definition. Although

spermatozoa have been found in an histological preparation of monkey testis of $2\frac{1}{12}$ years, the earliest record for a fertile impregnation in this laboratory is $3\frac{4}{12}$ years.

A typical male monkey, Mm 440, was born in the laboratory on April 30, 1937, and showed approximately linear

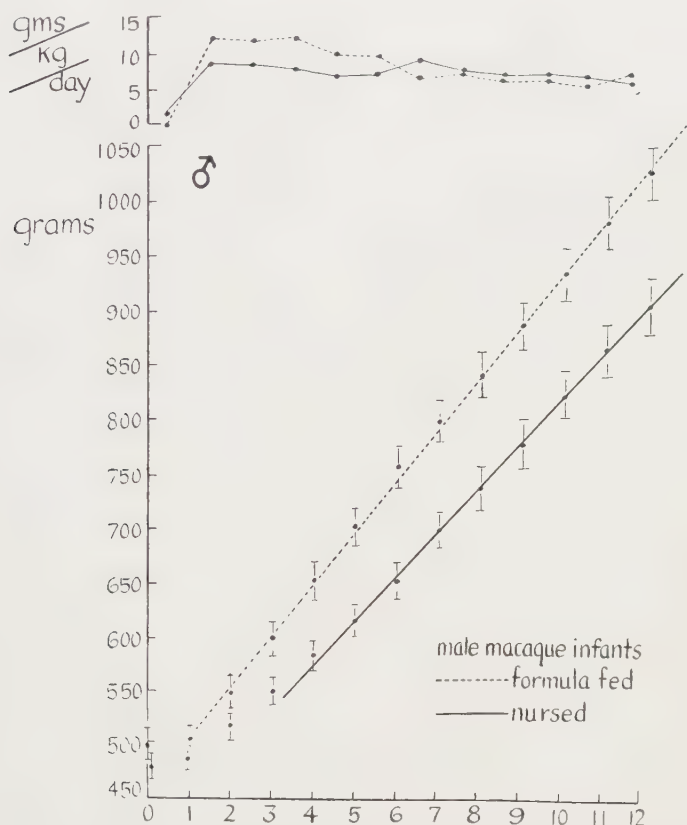


Fig. 11 Growth of nursing and formula-fed male infants during the first 12 weeks of life. Means and standard errors of the mean are shown.

growth for the first 18 months, then a levelling out (fig. 12). The adolescence growth spurt began at $2\frac{6}{12}$ years, at a time when the testis had definitely begun to increase in size. The periodic fluctuations in weight shown after the animal has matured are "administrative artefacts." It has been

customary in this laboratory to rest animals over the summer months and to begin breeding in the fall. The isolated male shows a great decrease in general physical activity during this time, with a corresponding gain in weight.

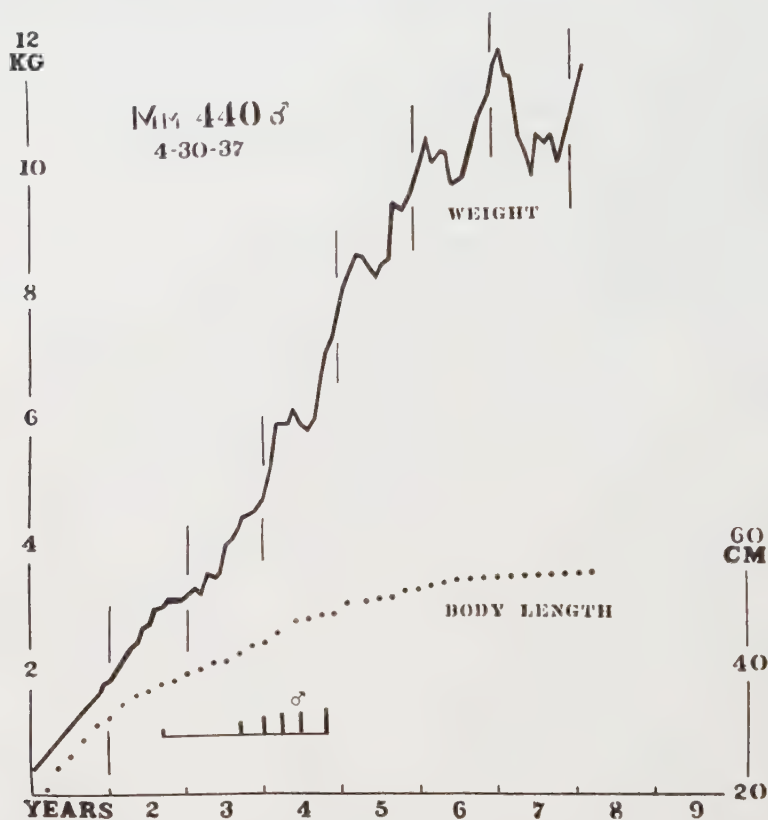


Fig. 12 Growth of a typical male macaque during an eight year period. Body weight and sitting height are shown. Comparable testicular size (greatest axis) of testis) is indicated in relation to age, and the point at which this animal sired its first infant is shown by the male symbol. See text for explanation of spiking in weight.

Body length (crown-rump). Sitting height increase with age is shown as a mean curve with one and two standard deviations (fig. 4) and tabulated (table 8). The monthly increments of sitting height appear in conjunction with simi-

TABLE 8

Crown-rump length, in centimeters, of male macaques in relation to chronological age taken month by month. Numbers of animals at successive times are shown, with mean lengths and standard deviations

YEARS	MONTHS															
	BIRTH			1	2	3	4	5	6	7	8	9	10	11	12	
NO. OF ANIMALS																
22 — 23 — 24																
0	Mean	19.6	21.6	23.4	25.2	26.9	28.5	29.9	30.9	31.9	32.6	33.5	34.3	35.0	35.0	
	Std. dev.	1.2	1.2	1.3	1.6	1.5	1.7	1.7	1.7	1.7	1.9	2.0	2.0	2.0	2.1	
1	No.	21														
	Mean	35.7	36.4	37.2	37.8	38.4	38.8	39.1	39.3	39.8	40.3	40.8	41.3	41.3	41.3	
2	S.D.	2.3	2.2	2.0	2.1	1.8	1.7	1.7	1.7	1.9	1.9	1.9	1.9	1.9	1.8	
	No.	16	17													
3	Mean	41.8	42.1	42.7	43.1	43.1	43.6	44.1	44.4	44.9	45.6	46.1	46.4	46.4	46.4	
	S.D.	1.8	2.3	2.3	2.4	2.4	2.6	2.7	2.7	2.7	2.7	2.4	2.2	2.1	2.1	
4	No.	15	14	13												
	Mean	46.9	47.4	47.6	48.2	48.6	49.0	49.4	50.1	50.5	50.8	51.2	51.5	51.5	51.5	
5	S.D.	2.1	2.1	2.1	2.1	2.1	2.1	2.0	2.2	2.2	2.4	2.5	2.4	2.4	2.4	
	No.	11														
6	Mean	51.7	51.9	52.2	52.6	52.8	53.0	53.1	53.2	53.3	53.4	53.6	54.1	54.1	54.1	
	S.D.	2.4	2.5	2.5	2.5	2.5	2.6	2.7	2.6	2.6	2.6	2.5	2.5	2.1	2.1	
7	No.	8														
	Mean	54.9	55.0	55.1	55.1	55.3	55.2	55.6	55.8	55.8	55.8	55.8	55.8	56.0	56.0	
8	S.D.	1.8	1.9	1.8	1.9	2.1	2.2	1.7	1.5	1.5	1.5	1.5	1.5	1.5	1.8	
	No.	3														
9	Mean	56.2	56.2	56.2	56.8	56.8	56.8	57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0	
	S.D.	1.6	1.6	1.6	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	

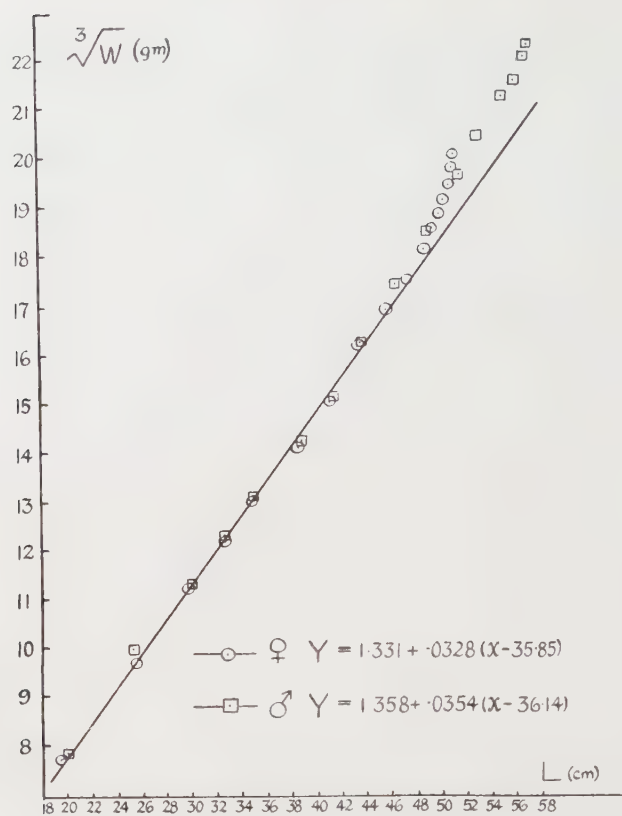


Fig. 13 Cube root of average weight in grams is plotted against the average sitting height in cm for male and female macaques.

TABLE 9

Ponderal index in *Macaca mulatta*: $\frac{\text{Wt (kg)} \times 100}{\text{sitting height (cm)}}$

	MALE	FEMALE
Birth	2.50	2.39
6 months	4.85	4.75
12 months	6.27	6.24
24 months	8.35	8.26
36 months	11.40	10.52
48 months	14.60	12.27
60 months	16.10	13.35
72 months	17.80	14.40
84 months	19.30	15.63

lar data for females (fig. 8). The male curve shows a distinct and prolonged rise beginning at 2½ years and continuing into the 4th and 5th years, surpassing the increment curve for females and confirming in general the conclusions reached for weight increments in the male macaque.

Changes in form of male and female macaques. Gross changes in form have been expressed by a ponderal index (table 9) showing the ratio: $\frac{\text{weight (kg)} \times 100}{\text{sitting height (cm)}}$. The values so obtained may be compared directly with those for human and chimpanzee presented by Gavan ('53).

DISCUSSION

The objective of the foregoing presentation has been to give basic growth data for the common laboratory primate, the Rhesus monkey (*Macaca mulatta*); as such, the charts and graphs are largely self-explanatory. They cover what may be roughly estimated to be the first third of the life span of this animal. For the human, a comparable epoch has been covered in a series of detailed and painstaking studies, some emphasizing the infantile period (Davenport, '38; Wetzel, '34), others the pre-adolescent and adolescent period (Greulich et al., '38; Shuttleworth, '38; Davenport, '26, '38; Collins and Clark, '29; Boas, '32; Greulich et al., '42; Simmons and Greulich, '43; Shuttleworth, '49a, '49b) and extending into early adulthood. For the chimpanzee, an 11 year study was presented by Spence and Yerkes in 1936, and follow up studies on this colony of great apes maintained in the Yerkes Laboratory at Orange Park, Florida have appeared (Grether and Yerkes, '40; Gavan, '53). For growth and developmental aspects of Rhesus monkeys in the Carnegie Colony at Baltimore, we have the article of Schultz ('33). A detailed comparison of the various growth patterns of primates will not be attempted here; rather, certain aspects of the present macaque studies which underline their specifically "primate" nature will be briefly commented upon.

Several phases of the human growth data were dealt with by Tanner ('51-2), who unfortunately did not have available

at that time extensive growth data for macaques. During the first months of life, the macaque shows falling weight-increment and sitting height-increment curves (figs. 5, 6, 8) corresponding to the negatively accelerated weight and height increment curves of man and chimpanzee. This phase is followed by a plateauing or by a slowly rising curve, and then by a very pronounced puberal rise, or "adolescent spurt" as described for the higher primates. Thus, weight increment curves in macaque correspond to those drawn by Tanner ('51-'52) from assorted data in the human, and to that of Grether and Yerkes ('40) for the chimpanzee. The sitting height increment curves follow in general form those for standing height in man.

Calculated on the basis of equivalent weight at birth, the growth of the macaque exceeds that of the human by a considerable margin. Otherwise stated, the human infant increases its weight 3-fold in the first 12 months and the macaque monkey $4\frac{1}{2}$ -fold; the chimpanzee is intermediate with about a $3\frac{1}{2}$ -fold increase. The increases in sitting height, however, run fairly parallel in monkey and man for the first 12 months at least. Between the first and the 12th month, each adds about $\frac{1}{3}$ to its sitting height; at one month, the human/monkey sitting height ratio is 16.4/1; at 12 months 14.0/1.

Gross changes in form are revealed by some such figure as a ponderal index (table 11), or by regression curves as described by Gavan ('52, '53). Comparison with figures given by Gavan ('53) show that the large primates have a much greater ponderal index than monkeys, but that the index for monkeys increases at a faster rate. In the large primates also, the indices for males and females vary in a complex fashion. While males in general show a higher index than females, this relationship is reversed in chimpanzees between the ages of 5 and 7 years, and in man between 5 and 14 years. In monkeys, the male index tends always to be slightly higher than that for females up to $3\frac{1}{2}$ years, then becomes definitely and progressively higher. Study of a regression curve of the cube root of weight on sitting height for male and female

monkeys (cf. Gavan, '52, '53) shows virtually superimposable straight lines up to the 4th year (fig. 13); Statistical analysis also showed no significant differences in the characteristics of the curves. Beyond 4 years, both male and female monkeys diverge in the direction of a greater weight for a given crown-rump length. This can be interpreted in terms of a greater deposition of fat or greater overall hydration of cells or connective tissue components consequent on hormonal adaptations occurring after sexual maturation. While the female weights and sitting heights tend to reach a plateau after the 5th year, these functions in the male continue to augment at least up to the 7th year, and probably beyond.

The weight increment curves for early and late maturing female macaques show a close resemblance to the standing height increment curves for early and late maturing girls presented by Shuttleworth ('38, fig. 138). For the human, as shown also by Simmons and Greulich ('43), the girl experiences the greatest increment in standing height during the year preceding the year of menarche, whereas the mean maximum increments in weight tend to be spread over a two year period. The sitting height data for monkeys, lacking the long bone component of growth, show a definite but less remarkable change during this phase of growth. However, the prolongation of the stimulus to height and weight increase in the male, as compared with the female, is very well marked in the macaque. For a general discussion of puberal growth relationships, the reader is referred to Tanner's paper ('51-2).

Certain features of the growth of infant macaques show interesting parallels with the human. Male birth weights exceed those of the female by the same fraction, approximately, in both. The post-natal weight loss in the human infant is well known. It generally occurs in the monkey, even when efforts are made to maintain hydration. Some monkeys show no weight loss, and in others the loss is considerable and the rate of regaining slow, so that the curve is skewed to the right, leading to rather large standard deviations (tables 1, 5). A strict interpretation should not be placed on these

values. In the human, 26% of infants are reported to regain their birth weight in 7 days, and 52% in 10 days (Thompson, '51), i.e., somewhat slower than in the monkey. By combining data from the papers of Thompson ('51) and of Meredith and Brown ('39), the male human infant appears to double his birth weight in 119 days, compared with 90 days for the male monkey, and the human female infant in 147 days, compared with 92 days for the female monkey. Other comparative aspects of the gain in weight in infant macaques have been mentioned above.

A few general remarks may be appended. The significant features of the growth curve of the monkey are the same as those which characterize the human growth curve, and may be presumed to reflect, at the appropriate times, the action of comparable hormonal factors. The infantile period in the monkey show the human parallels of birth trauma, helplessness, and relatively slow growth. Sexual maturation, for an animal of this size, is delayed. The monkey experiences a menstrual, rather than estrus cycle, and its mean length, 28 days, is the same as that of man. The attainment of sexual maturity proceeds by a series of frequently irregular, usually anovulatory periods in the female, and in the male by a prolonged period of testicular enlargement. Pregnancy, again for an animal of this size, occupies the relatively prolonged period of 6 months. These events are superimposed upon a pattern of growth which parallels, in a foreshortened but remarkably similar form, that of the human, and which appears to be characteristic of primates. These considerations point to the conclusion that this form is ideally suited to the experimental study of many phases of growth and development as a paradigm of man. It is likely, for example, that aspects of dental development in man may be clarified by detailed studies under experimental conditions in the monkey. Also, an extension of studies to the aged monkey ought to add to our understanding of the physiology and pathology of senescence in man.

SUMMARY

1. Fifty female and 28 male monkeys (*Macaca mulatta*) born in the Yale University Obstetrical Colony were initially available for long time studies of normal growth. Weights and sitting heights were recorded at frequent intervals. The period from birth to 7 years of age is included in the present report, and growth is recorded in relation to chronological age in a series of tables and charts. Weight and sitting-height increments at successive ages are also presented.

2. The relatively high rate of growth at birth falls off in the first 6 months, and is then resumed after a levelling off period of about 18 months of age in the female and 24 months in the male, corresponding to the initiation of maturation. The "adolescence spurt" appears early in early maturing females and later in late maturers. Weight and sitting height increments in the male surpass in size those of the female, and are also more prolonged in time.

3. Seventy-two female and 85 male monkey infants were closely followed during the first three months of life to determine the times of regaining and of doubling their birth weights. Smaller groups of 30 to 40 animals of each sex were studied for the influence of nursing and formula-feeding respectively on their growth characteristics.

4. The growth pattern of monkeys is compared with those described for man and chimpanzee.

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A BLOOD GROUP GENETICAL SURVEY IN WEST NAKANAI, NEW BRITAIN¹

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The present investigation was carried out in 1954 along the Hoskin's Peninsula which is located on the north central coast of New Britain Island in the Territory of Papua and New Guinea. The people concerned were the West Nakanai, a coastal dwelling group numbering about 4000. The term West Nakanai apertains to a geographic and linguistic group rather than to a distinct physical type. No evidence was uncovered to suggest that the West Nakanai had in the past lived in the interior and migrated to the coast, as other tribes have done and are doing at the present time along the northern coast. The West Nakanai occasionally marry a "bush" inhabitant, but such marriages are rare. Outbreeding when it does occur, is customarily with other coastal people, especially with those inhabiting contiguous areas, and from what was seen of these people, they are phenotypically indistinguishable from the West Nakanai. One of us (D. R. S.), a member of the field

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expedition is of the opinion that the West Nakanai represent a typical Melanesian society, both culturally and physically. The West Nakanai territory extends from the village of Kovalakese north-west along the Hoskin's Peninsula some 25-30 miles to the village of Koimumu. There are 19 other villages situated between these villages, and a further 4 villages 2-5 miles inland from the coast. All villages were visited.

Blood group frequencies (A-B-O) for the New Guinea area prior to 1939 have been tabulated by Boyd ('39). Stirling ('43) made the following statements regarding the native peoples of New Guinea:

"In a broad sense the New Guinea natives can be divided into three groups: the Negritos, the mountain tribes of the interior; the Melanesians of the north and east coast; and the Papuan of the interior lowlands and western coast . . . The Papuan racial stock evidently came into New Guinea at an early date following the Negrito migration from the Indonesian area. They spread over most of the island and may be considered the most characteristic stock making up its present population."

Birdsell ('48) in discussing New Guinea said:

"The aboriginal inhabitants of New Guinea and Melanesia contain the same racial ingredients as the trihybrid Australians, (Negrito, Murrayian and Carpentarian) with small additions of Mongoloid genes in some areas. In contrast to Australia, these populations are basically negritic in their general composition as a result of the rain forest environment of this area. The Mongoloid element is a recent addition dating from the introduction of an agricultural economy into Melanesia, an event which profoundly affected population densities and environments and resulted in the present heterogeneity of groups in these islands."

Graydon and Simmons ('45) examined 200 blood samples from adult full-blooded natives most of whom originated in coastal and river districts of the Territory of Papua. The individuals were considered to be representative of the inhabitants of the south-eastern coastal districts of New Guinea — an area at that time which had not been included in any previously reported blood group survey.

Comparisons were made of the A , B , O and m , n frequencies for the Daru-Kikori area and other south coast districts from Kerema to Abau. Considerable differences in relation to values for B and for n were observed in the two areas. Statistical tests applied to the combined results suggested that the group examined was not genetically homogeneous, and perusal of the figures for the separate districts revealed evidence supporting this contention. (A map of the area was provided in this paper.) Simmons, Graydon and Woods ('46) extended the above observations by testing a further 255 blood samples obtained in the administrative districts of Daru and Kikori (the river delta area) and Kerema, and obtained results which added confirmation to the initial findings. Sanger, Walsh and Kay ('51) reported results for 141 blood samples collected at the Port Moresby hospital. Most of these samples were from natives originating in some 16 Papuan districts. Walsh, Kooptzoff, Lancaster and Price ('53) tested bloods from 357 native members of the Royal Papuan Infantry Battalion, which apparently was a miscellaneous group. The blood grouping results for a total of 498 natives in the two latter surveys were examined in relation to the following districts: Gulf, Central, Northern, Western, Sepik, Morobe and Milne Bay, and also in relation to the language spoken, that is, Melanesian or Papuan. (The districts referred to are in New Guinea and the Territory of Papua.) The conclusion reached was the same as that reached by Graydon and Simmons ('45) namely, that native groups of different districts were not genetically homogenous.

Work carried out in New Guinea by the Melbourne authors in 1950-51 relates to native groups in the Central Highlands at Chimbu, Nondugl, Mt. Hagen and Goroka, and also to pigmy people in the Nassau Mountains of Dutch New Guinea [Semple, Simmons, Graydon, Randmae and Jamieson ('56), and Semple, Graydon, Simmons and Franken ('56)]. Other surveys made on native peoples of the New Guinea area include Admiralty Islanders reported by Simmons and Graydon

('47), and the Bainings of New Britain by Semple, Simmons et al. ('56).

The present investigation records blood groups and gene frequencies for the West Nakanai of New Britain, and these results are presented in tables 1 and 2. Gene frequencies and blood groups for all the peoples referred to above are in tables 3 and 4 for purposes of comparison.

TABLE 1
*A-B-O, M-N and Rh blood groups and gene frequencies in
West Nakanai, New Britain*

NO. TESTED	BLOOD GROUPS				GENE FREQUENCIES		
	O	A	B	AB	A	B	O
103	48	17	35	3	.103	.206	.691
	46.6%	16.5%	34.0%	2.9%			
103	M	MN	N		m	n	
	3	41	59		.228	.772	
	2.9%	39.8%	57.3%				
94	Rh ₁ Rh ₁	Rh ₁ Rh ₀	Rh ₂	Rh ₁ Rh ₂	R ¹	R ²	R ⁰
	78	9	1	6	.910	.039	.051
	83%	10%	1%	6%			

TABLE 2
Summary of other tests performed on the West Nakanai

S+ M-N-S	Rh ₀ (D ^u) Variants	rh ^w (C ^w)	P+	Le (a+) Lewis	Fy (a+) Duffy	K+ Kell	P.T.C. TASTE REACTIONS		
							Sex	Tasters	Per cent
1/46	8/94	0/46	16/46	5/46	46/46	0/46	Males	177/276	64.1%
2%	9%	0%	35%	11%	100%	0%	Females	54/71	76.1%
							Totals	231/347	66.6%

MATERIALS AND METHODS

Blood samples were collected by the finger prick technique from 195 natives in 23 villages, and not more than one member of a family was included in the series. There were, however, several instances of first cousins which are the closest con-

SURVEY IN NEW BRITAIN

279

POPULATION	AUTHORS	NO. TESTED	A	B	O	NO. TESTED	m	n	NO. TESTED	R ¹	R ²	R ⁰	R ²
Papuans, Daru-Kikori, Papuan, Other districts.	Graydon and Simmons ('45). Simmons, Graydon and Woods ('46), and Simmons, Graydon and Semple ('53).	228	.182	.196	.622	228	.039	.961					
Totals		455	.197	.160	.642	455	.133	.867	100	.945	.020	.020	.015
New Guinea: Melanesian speaking, ²	Sanger, Walsh and Kay ('51), and Walsh, Kooptzoff and Price ('53).	181	.224	.093	.683	170	.197	.803	171	.909	.050	.041	0
Papuan speaking. Total tested		216 498	.251 .245	.178 .134	.571 .621	172 443	.087 .152	.913 .848	201 472	.908 .915	.045 .048	.047 .037	0 0
New Guinea: Goroka.		123	.168	.102	.729	123	.081	.919	123	.801	.129	.071	0
Chimbu, Nondugl, Mount Hagen. Totals	Semple, Simmons, Gray- don, Randmae and Jamieson ('56).	362 485	.205 .195	.179 .159	.616 .646	365 488	.021 .036	.979 .964	362 485	.923 .892	.064 .081	.013 .028	0 0
Pygmies. Dutch New Guinea.	Semple, Graydon, Sim- mons and Franken ('56).	139	.075	.139	.786	138	.101	.899	137	.850	.121	.029	0
Admiralty Is- landers, Manus Island.	Simmons and Graydon ('47).	112	.145	.134	.721	112	.339	.661	112	.933	.029	.038	0
Bainings New Britain.	Semple, Simmons et al. ('56).	77	.297	.252	.451	77	0	1.000	77	.818	.168	.014	0
West Nakanai New Britain.	Present survey.	103	.103	.206	.691	103	.228	.772	94	.910	.039	.051	0

¹ The frequencies presented in this table have all been calculated from the original data by one of us (J.J.G.) using Bernstein's corrections for A, B, O, and for Rh, a gene counting method suitably modified where necessary to take account of genotype frequencies not unequivocally determined. These figures which differ slightly from those presented in the original publications closely approximate those obtained by the method of maximum likelihood.

² The individuals were classified in Sydney as Melanesian speaking and Papuan speaking from a list of names and villages provided.

TABLE 4

Other blood groups in New Guinea area

POPULATION	AUTHORS	NO. TESTED	S POSITIVE	<i>mS</i>	<i>mS</i>	<i>ms</i>	<i>ms</i>	P	Lewis Le ^a	Duffy F ^{ya}	Kell K	P.T.C. TASTERS
New Guinea:												
Melanesian speaking.	Sanger et al. ('51) and Walsh et al. ('53).	170	20.6%	.195	.002	.696	.107 ¹	..	..	..	..	..
Papuan speaking.		172	25.0%	.086	.001	.779	.133	..	..	..	..	..
Total tested		443	23.3%	.145	.007	.731	.117	Present	Present	252/252 100%	Absent	..
New Guinea:												
Goroka.	Semple, Simmons	123	12.2%	.076	.005	.861	.058	..	..	..	..	..
Chimbu, Nondugl, Mount Hagen.	et al. ('56).	235	28.1%	.025	.005	.823	.147	..	..	..	..	..
Total tested		358	22.6%	.042	.005	.838	.115 ²	182/318 57.2%	0/316 0%	70/70 100%	1/52	179/330 54.2%
Dutch New Guinea: Pygmies.	Semple, Graydon et al. ('56).	137	1.5%	.102	0	.890	.008	57/91 63%	0/116 0%	27/30 90%	..	62/126 49.2%
New Britain: Bainings.	Semple, Simmons et al. ('56).	77	0	0	0	1.000	0	34/38 89.5%	15/75 20%	22/22 100%	..	..
New Britain: West Nakanai.	Present survey	46	2.0%	.234	.005	.755	.006	16/46 35%	5/46 11%	46/46 100%	0/46 0	231/347 66.6%

¹ The M-N-S frequencies given in the first three rows of the table were derived from calculations made according to the method published by Graydon, Simmons et al. ('52), and suitably modified to be applicable to series where no MS occurs. The frequencies obtained differ appreciably from those appearing in the original papers.

² *ms* + *mS* does not equal the value for *m* given in table 3 which applies to a group of 488 individuals. The difference is due to the inclusion, in those tested with anti-S serum, of a higher proportion of natives from Goroka where *m* is more common than other parts of the Central Highlands.

sanguinal relationships represented. Males and females of all age groups were chosen in order to have as many generations represented as there were in the population. All blood sample collections were made in the villages, and up to 4 hours elapsed before refrigeration of samples was possible. Samples were then held in the field in a kerosene refrigerator for about a month, and due to a misunderstanding at the port of departure in New Britain, the samples were not re-iced during the 7 days of air transport to Melbourne. There were 92 samples haemolysed on arrival, and these were discarded. Other samples progressively haemolysed during laboratory testing, and these were also discarded. Despite this loss, all villages were still represented in the final series tested. Of the specimens received, 103 were satisfactory for A-B-O and M-N testing, 94 for Rh testing and 46 for other blood group determinations.

The methods employed for collecting and testing the blood samples have been described again in detail by Simmons, Graydon, Semple and Taylor ('51).

The loss of samples in the present survey illustrates the need for asepsis in the collection of blood, and that immediate and continuous refrigeration of samples is essential to prevent haemolysis.

RESULTS AND DISCUSSION

The blood groups and gene frequencies. The calculated gene frequencies for the samples tested are —

$$A = .103, B = .206, O = .691.$$

No tests for the subgroups of A were performed.

In the M-N types,

$$m = .228, n = .772. \text{ Of 46 samples tested, one was S positive.}$$

The Rh gene frequencies are —

$$R^1 = .910, R^2 = .039, R^0 = .051.$$

No example of rh^w (C^w) was found in 46 samples tested.

Rh₀(D^w) variants. Eight of 94 samples failed to show agglutination with anti-Rh₀ serum, which was unexpected. These samples gave strong agglutination with anti-rh' (C) serum,

and did not react with anti-rh'' (E) or with anti-hr' (e). The 8 samples were then tested by means of the Coombs anti-globulin test after having been sensitized with specially selected potent anti-Rh₀ blocking serum. In each instance a positive reaction was obtained which indicated that all of the 8 samples contained a "low-grade" Rh₀(D^u) variant. It should be noted that each sample gave normal agglutination with A-B-O and M-N testing sera. From the above results it seems likely that these West Nakanai individuals are homozygous in relation to the Rh₀ variant, and that they are of phenotype Rh₁Rh₁.

Wiener indicates the presence of Rh₀ variants in all Rh positive phenotypes with a Germanic R, while English workers refer to them as D^u. On this basis the calculated frequency for the Rh₁ (CD^ue) variant is .29.

Gene *r'* has not been demonstrated in the Melanesian peoples to date. The Melbourne workers found all of the initial 455 Papuan blood samples to be anti-Rh₀(D) positive, and the Sydney workers obtained a similar result with 472 New Guinea-Papuan bloods. Semple, Simmons et al. ('56) found no evidence of Rh₀ variants in 485 natives in the Central Highlands of New Guinea. Semple, Graydon et al. ('56) found no Rh₀ variants in 137 natives of Dutch New Guinea. Walsh ('52) in testing 20 blood samples from Rabaul, New Britain, found one to possess a "low-grade" Rh₀ variant. The native is referred to in the text as a New Guinea native, but the tribe or district of origin of this individual was not given. One may, therefore, assume that Rh₀ variants are absent or rare in New Guinea, but are common in some peoples of New Britain, although no example was observed in 77 Bainings (Semple, Simmons et al., '56).

Other blood group results for West Nakanai (table 2) were —

$$P = 35\%, \text{ Le}(a+) = 11\%, \text{ Fy}(a+) = 100\%, \text{ K}+ = 0.$$

P.T.C. taste reactions. The inherent difficulties in obtaining accurate taste reactions are generally recognized, and these were greatly enhanced among the West Nakanai because

these people are inveterate betel-nut chewers. It was not always possible to have them rinse their mouths prior to testing. Since the most common location of the gustatory organ is on the walls of the vallate and foliate papillae of the tongue, the taste papers were placed as far posteriorly as feasible without provoking a gagging reaction. By this method it was hoped to minimize any masking effects the betel-nut might have had on these people to phenyl-thiocarbamide. Of 276 males tested, 177 (64.1%) were recorded as tasters; while of 76 females tested, 54 (76.1%) showed this ability. The ratio of female to male tasters was 1.19, which is well within the range tabulated by Boyd ('50), page 280.

Gene frequency comparisons

Examination of tables 3 and 4 shows that the . . .

- highest A .297 was in Bainings,
- lowest A .075 was in Pygmies, Dutch New Guinea,
- highest B .252 was in Bainings,
- lowest B .039 was in Melanesian speaking natives,
- highest O .786 was in Pygmies, Dutch New Guinea.
- lowest O .451 was in Bainings,
- highest m .339 was in Admiralty Islanders.
- lowest m 0 was in Bainings,
- highest R^1 .945 was in Papuans.
- lowest R^1 .801 was in Goroka natives.

Although significant differences are observed for the three blood group systems, A-B-O, M-N and Rh, the general picture for the Melanesian people is one of similarity in each system, thus: O is high with A and B of low to moderate values, and values of n and R^1 are exceptionally high. In the Rh system, the three genes R^1 , R^2 and R^0 are sufficient to account for the Rh types observed, and only in the first Rh survey in Papua was R^2 reported to have been found by Simmons et al. ('46). This early observation and subsequent failure to obtain confirmatory evidence of the presence of the R^2 gene in the Territory of Papua and New Guinea caused the present authors to take stock of the situation. Over 1,000 Rh tests have been performed (table 3), and in only three instances did blood

samples give the serological reactions of Rh_z . Records show that the three individuals were all from Daru Island, which was one of the nearest points of contact for the interchange of visits in the past with Australian aborigines. The presence of R^z in Australian aborigines was first reported by Simmons and Graydon ('48), and its distribution in various States including Queensland appeared to be patchy. This observation has subsequently been confirmed, and the presence of up to 20% R^z in some tribes in Western Australia was referred to in a preliminary report by Simmons, Graydon and Birdsell ('53). It is suggested that the gene R^z is not original to the Melanesian people, but has been introduced into natives at Daru, Papua, by admixture with Australian aborigines. The absence of R^z in New Guinea, New Britain, and the Admiralty Island lends considerable support to the above suggestion.

The finding that 77 Bainings were all of type N is unusual. However, as Papuans at Daru-Kikori have $n = .961$, and as the Central Highlanders of New Guinea have $n = .979$, it is not surprising that a group of natives was encountered who are entirely of type N.

Sanger ('50) and Sanger, Walsh and Kay ('51) presented M-N-S frequencies for New Guinea natives and stated:

"It can be calculated that 26% of M genes are MS, and 10.5% of the N genes are NS. This ratio of MS to NS of 2.5 to 1 is close to that found in England, viz, 2.8 to 1."

Simmons, Graydon and Semple ('53) in a summary of their M-N-S frequencies for Pacific peoples pointed again to the more frequent association of S with N rather than with M. In table 4 of the present paper, M-N-S frequencies calculated by one of us (J. J. G.) show that in natives of New Guinea — Papua, S is more frequently associated with N, and that the frequencies presented differ appreciably from those given in the original papers.

West Nakanai and Bainings. Both peoples are inhabitants of New Britain. However, Bainings have $A = .297$ and West Nakanai $A = .103$, while in both peoples B is rather similar. In Bainings $n = 1.000$, $R^1 = .818$, and in West Nakanai $n =$

.772, $R^1 = .910$. S of M-N-S is of low value or absent in both. The P percentages show wide variation, Le(a+) is present in both in moderate percentages, and each group has Fy(a+) = 100%. The variations in frequencies seen here in local groups are possibly like those already referred to for groups throughout New Guinea-Papua, which, according to Graydon and Simmons (loc cit) are not genetically homogenous.

Sickle-cell trait. Swindler ('55) found no evidence of the sickle-cell trait in the West Nakanai.

Simmons, Graydon and Birdsell (loc. cit.) in a preliminary communication reported the absence of the sickle-cell trait in 125 unmixed Australian aborigines in Western Australia. This was the first report of sickle-cell trait tests in the Australian area.

SUMMARY

Blood samples from the West Nakanai of New Britain have been tested for the blood groups A-B-O, M-N-S, Rh, P, Le^a, Fy^a and K. P.T.C. taste tests were also carried out.

Gene frequency data for peoples of Papua, New Guinea, Dutch New Guinea, New Britain and the Admiralty Islands are presented for comparative purposes.

It is considered that the blood group frequencies reported for the West Nakanai fall within the limits expected for Melanesia, and that further confirmation has been obtained for an earlier statement that the population of Melanesia is not genetically homogenous.

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GROWTH OF THE NORMAL FOOT DURING CHILDHOOD AND ADOLESCENCE¹

LENGTH OF THE FOOT AND INTERRELATIONS OF FOOT,
STATURE, AND LOWER EXTREMITY AS SEEN IN
SERIAL RECORDS OF CHILDREN BETWEEN
1-18 YEARS OF AGE

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FIVE FIGURES

INTRODUCTION

Our study of children who have abnormalities of growth in their lower extremities has repeatedly been compromised by the lack of normal standards of reference on which to base analyses. There are, for example, no suitable values for the lengths and distribution of lengths of the foot in boys and girls which cover the span of years from the age of walking until mature length is achieved. Meredith's ('44) compilation of available data was of great assistance, but served to emphasize the need for the completion of comprehensive standards which would cover the entire age range.

Several basic interests may be furthered by expanding the knowledge of growth in this area. Primarily, information is needed on the growth of the foot itself in order to learn at what age the greater part of its length is attained and how much children of both sexes and of all ages may normally deviate. Such information would make it possible to assess the status of a given foot at any age in comparison with the normal. In the second place, an additional index of practical value in judging the pattern of individual maturation might

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be provided by an evaluation of the growth of the foot at succeeding ages. If, as has been implied in the literature, the foot matures at an earlier age than other parts of the body, the changing relationships of the foot to the lower extremity and to stature should be useful criteria of the developmental status of the child. And thirdly, the result of inhibition in the growth centers of the foot during childhood is little known; information on the growth of the foot as a whole as well as of its various segments is needed in the timing of certain orthopedic procedures since injury, whether accidental or due to surgery, may considerably affect the mature size of the foot.

The material to be presented here is distinctly longitudinal in nature, the lengths of the weight-bearing foot having been obtained on a large semi-longitudinal series and the resultant average values having been checked against those derived from 20 subjects who had been followed annually from birth through the age of 18 years. Stature and the lengths of the femur and tibia were also measured at least annually in the subjects of both groups, so that the relationships of the foot to height and to the length of the long bones could also be derived at yearly intervals throughout the entire period of growth.

We shall describe the length of the foot at each age and its changing rate of growth, particularly in relation to that of other parts of the body.

METHOD

(a) *Subjects.* A group of 512 patients who demonstrated normal muscle power in the neck and trunk and in one entire lower extremity were selected from the 1175 children who are being followed in the Growth Study of the Massachusetts Infantile Paralysis Clinics of The Children's Medical Center. All these patients have had serial observations of their growth, 75% of the group included in this report having been measured for 5 to 12 consecutive years. Anthropometric measurements of the length of the foot as well as of other parts of the body were made at regular intervals when the patients came in for special roentgenograms of the lower extremities.

A second series, consisting of 10 boys and 10 girls, provided a longitudinal reference. These subjects comprise part of a larger group of 140 normal children who are under study at the Department of Maternal and Child Health of the Harvard School of Public Health. These 20 were selected for this study of the length of the foot on the basis that they had complete records which extended from birth through the age of 18 years and which included serial roentgenograms of the foot as well as other roentgenographic, anthropometric and clinical data.

Both these series are representative of the public and parochial school population of greater Boston. No detailed sociological study has been made of the group with poliomyelitis but a rough assay indicated no real difference from that reported by Stuart ('39) for the "normal" series.

(b) *Anthropometric measurements.* The length of the right or left foot, whichever had no muscle involvement by poliomyelitis, was recorded. The feet were measured with a 17-inch wooden caliper having a spring attachment on the movable arm which held it at right angles to the base when the reading was made. The subjects stood in the caliper with the center of the back of the heel against the stationary arm and with the great toe centered along the base of the caliper. The movable arm was brought into firm contact with the tip of the great toe after the child was fully weight-bearing on both feet. Readings were made to the nearest millimeter.

Measurements made in this manner appeared to be reliable in that the lengths of the foot recorded by two pairs of technicians in a test group of 50 of these patients checked within 0.15 cm of one another, equivalent to an average error of but 0.8%.

Standing height and other anthropometric data were also recorded for both series of subjects at each examination.

(c) *Roentgenographic measurements.* Roentgenograms were made of the right foot in lateral non-weight-bearing position. The subject was positioned so that he was lying on the right side with the lateral border of the foot against the film in as nearly a "true lateral" position as possible. The tube was centered over the mid-tarsal region at a distance of three feet from the film. The technical factors were adjusted to record detail of soft tissue as well as of bone.

The measurements of total foot lengths which were derived from these films were made along a line tangent to the lowest portion of the os calcis and to the lowest portion of the head of the 5th metatarsal. Perpendiculars were constructed to this line through the most posterior point on the skin of the heel and through the most distal point of the skin of the great toe as well as through other

intermediate landmarks which will be reported elsewhere (Blais and Green, in prep.). The distance between these perpendiculars was recorded as the length of the foot.

The reliability of the measurements of total length from these films was the same as that for the caliper measurements, the average difference being 0.15 cm, or 0.8% error, when the same films were measured by two technicians. The error inherent both in the positioning of the subject and in the measurement of the part were in large measure controlled by inspection of the curves formed when the data were plotted for each individual, see (e) below.

The lengths of the femur and tibia, referred to in the text, were made from orthoroentgenograms for which the technique of measurement has been described previously (Anderson and Green, '48). Such films give the true lengths of the long bones, with minimal magnification or distortion.

(d) *Age interval.* Visits for both types of measurement were scheduled at annual and at 6-month intervals. The age of each child at each visit was recorded to the nearest half-month, correction being made for those who were measured off-schedule, see (e) below.

(e) *Interpolation.* All measurements were plotted according to the exact age of the individual on cross-section paper and the points connected to form curves. Graphic interpolation was used as indicated to complete the data. For example, if the age at examination were more than two weeks from that specified, if a measurement at a particular age were missing or if a doubtful measurement existed, an interpolated value was used.

Comparison of the averages derived from the raw data and from the more complete, interpolated data showed that the latter procedure did not alter the curves appreciably. On the other hand, this treatment of the material did allow the computation of individual increments in foot lengths at equal age intervals throughout childhood; since this particular information was desired, the interpolated values were incorporated into the averages reported below.

The length of the foot

A continuous norm for the length of the foot has been constructed from the 3128 caliper measurements obtained from the normal feet of the patients enrolled in this study. Average values as well as standard deviations were derived at each age for the boys and for the girls separately (fig. 1 and table 1). These are the only "standard tables" for the

length of the foot, so far as we know, which cover the entire age span from one through 18 years of age and which also indicate the expected range of normal variation throughout. The values presented here, moreover, are similar to those which have been previously suggested following observations of children over shorter intervals of time. The lengths of

TABLE 1

Length of the normal weight-bearing foot in centimeters

Measurements from heel to tip of great toe made from caliper measurements.
Semi-longitudinal series—285 boys, 227 girls

GIRLS				AGE	BOYS			
No. of cases	Mean	σ	Median		No. of cases	Mean	σ	Median
21	11.87	0.635	12.0	1	17	11.90	0.579	12.0
30	13.47	0.679	13.6	2	40	13.50	0.776	13.6
42	14.86	0.843	14.8	3	61	15.07	0.938	14.9
66	15.93	0.855	16.0	4	84	16.29	0.915	16.2
64	17.07	0.956	17.2	5	80	17.27	0.920	17.2
64	18.25	0.998	18.3	6	78	18.19	0.981	18.2
69	19.13	1.064	19.2	7	76	19.23	0.969	19.2
74	19.91	1.148	20.0	8	92	20.16	0.965	20.2
86	20.86	1.174	20.8	9	83	21.08	1.026	21.1
94	21.65	1.287	21.7	10	98	21.89	1.017	21.9
105	22.44	1.334	22.5	11	112	22.58	1.115	22.6
110	23.15	1.264	23.2	12	126	23.51	1.205	23.5
113	23.57	1.323	23.6	13	138	24.22	1.266	24.2
106	23.77	1.347	23.8	14	152	25.06	1.415	25.1
98	23.84	1.323	23.8	15	147	25.71	1.331	25.7
88	23.82	1.310	23.8	16	139	26.04	1.276	25.9
80	23.84	1.325	23.9	17	128	26.11	1.249	26.1
60	23.87	1.294	24.0	18	107	26.14	1.272	26.2

the foot derived from this series, for example, closely parallel those reported by Meredith ('44) on a semi-longitudinal series of Iowa City children between the ages of three and 10 years. The averages, as well as the spread of the individual values, were similar in the two groups although the feet of the children included in the present analysis were consistently smaller than those of the Iowa series which included subjects from

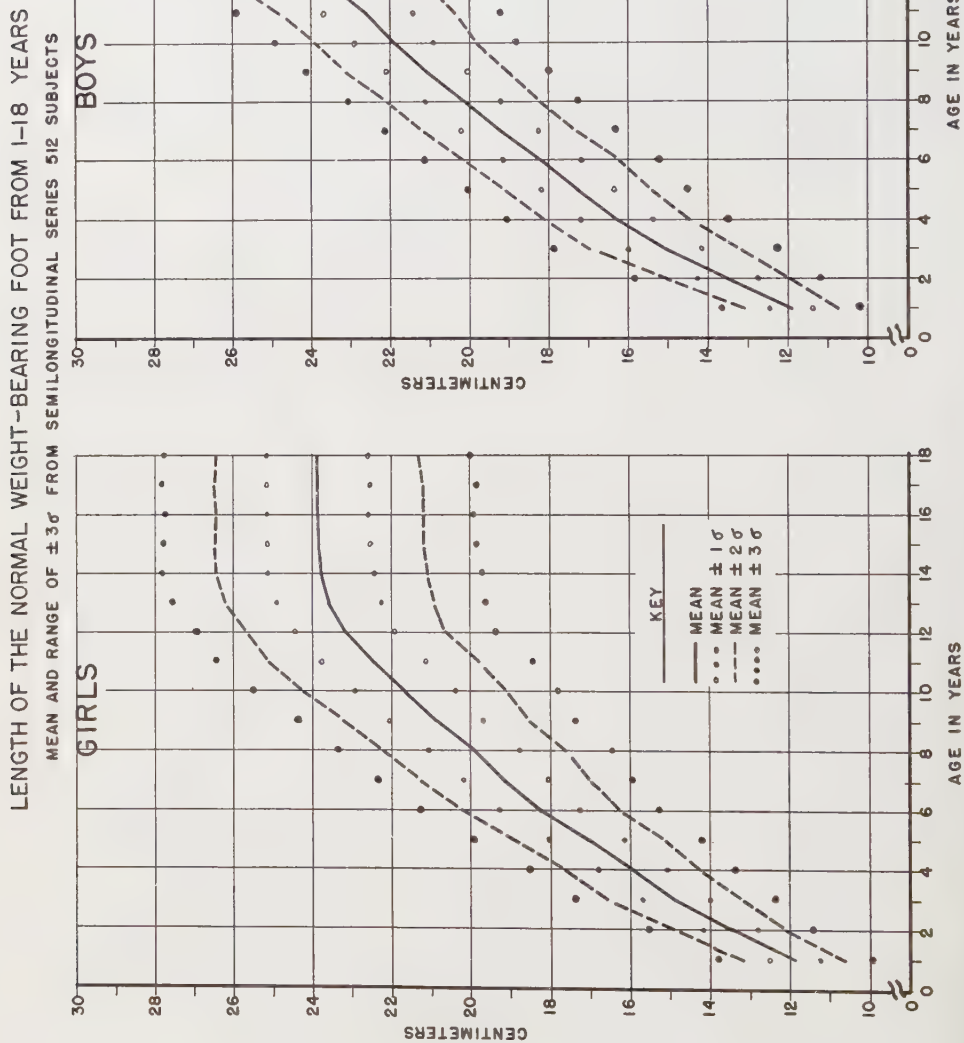


Fig. 1 Distribution of caliper measurements of length of the normal foot from heel to tip of great toe.

more rural areas who also had a greater proportion of North European ancestry. The mean lengths of the foot reported by Davenport ('32) on children from the Brooklyn Orphanage between the ages of 5 and 16, however, were considerably lower at all ages than the averages reported either by Meredith or in this communication.

Since the figures presented here are based upon a stable group which is particularly longitudinal in nature and since the actual values are in fair agreement with the fragmentary material previously reported, these standard tables may be used in defining pertinent deviations among children of a heterogeneous population from one year of age until adulthood.

(a) *Comparison of standard with longitudinal series.* The distributions obtained from these anthropometric measurements were checked against those derived from the small longitudinal series of subjects who had lateral roentgenograms of the foot at each age from one through 18 years. [To render the measurements from roentgenograms comparable to those made with the caliper, a correction factor was applied to the foot lengths obtained from the films. The correction factor (0.9741) was derived from a third series of 67 feet of 32 children and 4 adults who had measurements made by both techniques on the same day. Application of this factor in effect corrected both for the magnification which resulted from divergent roentgen rays and for the dissimilar positions used in the two methods.] This comparison served a three-fold purpose. In the first place, standards which were based upon the uninvolved extremity of patients with paralytic poliomyelitis of the opposite limb might well be criticized, so it behooved us to verify the results from a normal series with no pathology whatever. Secondly, it was desirable to check these values, which had been derived from a semi-longitudinal group in which each member was represented at an average of only 6 of the possible 18 age levels, against the more continuous data of a wholly longitudinal series. And finally, we wished to ascertain the degree of change in the

inter-relationships of foot, stature and the long bones at succeeding ages. Since this could best be done on a longitudinal series, it was essential to establish that the smaller series of children, whose feet were measured by a different

TABLE 2

Comparison of lengths of feet derived from two series

A. Semi-longitudinal series, caliper measurements

B. Longitudinal series, roentgenographic ¹ measurements

B. Longitudinal series, roentgenographic								
GIRLS				AGE	BOYS			
Mean A	Mean B	Difference			Mean A	Mean B	Difference	
		A-B	σ diff.				A-B	σ diff.
11.87	11.74	+ 0.13	0.260	1	11.90	11.92	— 0.02	0.193
13.47	13.75	— 0.28	0.214	2	13.50	13.91	— 0.41	0.217
14.86	15.13	— 0.27	0.201	3	15.07	15.26	— 0.19	0.239
15.93	16.25	— 0.32	0.180	4	16.29	16.21	+ 0.08	0.218
17.07	17.16	— 0.09	0.206	5	17.27	17.15	+ 0.12	0.235
18.25	18.07	+ 0.18	0.260	6	18.19	18.21	— 0.02	0.283
19.13	18.87	+ 0.26	0.285	7	19.23	19.25	— 0.02	0.304
19.91	19.74	+ 0.17	0.332	8	20.16	20.20	— 0.04	0.292
20.86	20.66	+ 0.20	0.377	9	21.08	21.11	— 0.03	0.299
21.65	21.41	+ 0.24	0.419	10	21.89	22.04	— 0.15	0.323
22.44	22.31	+ 0.13	0.417	11	22.58	22.93	— 0.35	0.329
23.15	23.14	+ 0.01	0.379	12	23.51	23.86	— 0.35	0.339
23.57	23.70	— 0.13	0.379	13	24.22	24.67	— 0.45	0.358
23.77	23.91	— 0.14	0.386	14	25.06	25.36	— 0.30	0.309
23.84	24.00	— 0.16	0.394	15	25.71	25.85	— 0.14	0.314
23.82	24.02	— 0.20	0.400	16	26.04	26.15	— 0.10	0.302
23.84	24.03	— 0.19	0.404	17	26.11	26.21	— 0.10	0.297
23.87	24.03	— 0.16	0.412	18	26.14	26.22	— 0.08	0.302

¹ Lengths which were measured from roentgenograms were multiplied by a factor, 0.9741, to compensate for non-weight-bearing position and also for magnification due to roentgen technique.

technique, provided values which were similar to those of these standards.

The two groups were, in fact, very comparable. The average lengths of the feet were similar at each age despite the great difference in the two methods which were used in the collection of their data. The absolute differences between the

means of the two series never exceeded 0.45 cm but even this maximum divergence, which was found in boys at age 13, was too small to be of statistical significance (table 2). The lengths of the foot measured from roentgenograms in the longitudinal series were, therefore, taken as being representative and relationships between their lengths were assumed to be valid for the larger series.

(b) *Sex differences.* At all ages below 13 years, the mean length of the foot was essentially the same for the boys and for the girls of both these series. Girls showed a tendency to have slightly smaller feet than boys but no difference of statistical significance was found between the means for boys and girls during the first 12 years of life; even the extreme values, while favoring the boys, were very similar for the two sexes in these early years (fig. 2). It is perhaps noteworthy that the girls did not exceed the boys in the average length of the foot in either series during the early-adolescent years, as is characteristic at 11 and 12 years of age in the average curves for both stature and for the length of the long bones.

Following the age of 12 years, the differences between the average lengths of the foot for boys and for girls increased rapidly: girls' feet grew very little after that age, only 0.7 cm on the average, whereas those of the boys showed an average residual increment of 2.6 cm. In the group of nearly 200 subjects who were followed to age 18, completion of growth in the length of the foot was observed to occur at varying ages, dependent upon the child's rate of maturation as judged by skeletal age and by clinical observations of the individual. In girls, the foot showed no further growth following the average chronological age of 14, mature length having been attained by that age in 75%. In boys, growth of the foot had terminated in 70% by the age of 16, two years later than girls, the average mature length of the male foot being about one inch longer than that of the female.

Changes of a comparable degree in the rate of growth of the foot were demonstrated at common stages of maturation

GROWTH OF THE FOOT: COMPARISON OF VALUES FOR BOYS AND GIRLS, 1-18 YEARS OF AGE

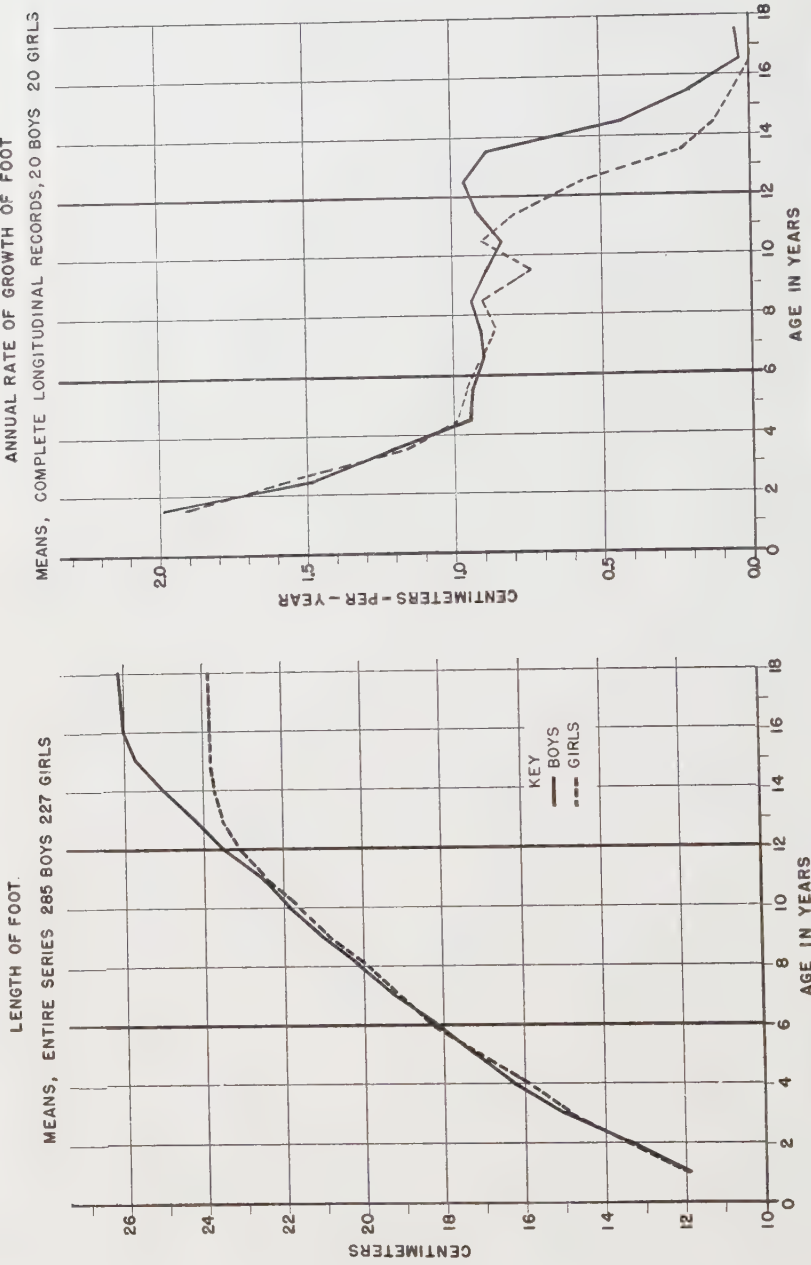


Fig. 3 Comparison of average yearly increment in length of foot for boys and girls. Patterns do not diverge until age 12.

Fig. 2 Comparison of average length of feet of boys and girls at each age. No significant difference between means until after the age of 12.

in both the boys and girls of these series. From the representative sample of 40 complete records which covered the years from one through 18, the annual increments were computed for each member and the mean rate derived at each age for the 20 boys and 20 girls (fig. 3). Despite the small size of the increments involved, a definite pattern of changing velocity of growth at various age levels emerged from these data. The rate of growth in the length of the foot in both sexes dropped rapidly from its high in infancy until 4 or 5 years of age when a plateau was reached with the yearly increment at about 0.9 cm per year. A brief "growth spurt" was often identifiable, usually between 10 and 11 years of age in girls and between 12 and 13 years in boys. This early-adolescent maximum increment averaged 1.2 cm per year in the 20 individual boys, 1.1 cm in the 20 girls, and was followed by a rapid decrease in rate, with all growth being completed three or 4 years after this spurt in growth.

Neither the length of the foot nor its mean rate of growth is different for boys and girls until after the age of 12; at that average chronological age, the feet of boys begin their most rapid adolescent growth while girls' feet show a marked deceleration in rate.

*The foot in relation to stature and length
of the lower extremities*

(a) *Rates of growth.* The sequential alterations in the rate of growth in the foot which were demonstrated above were of course far more pronounced in individual records than in average figures derived from children who exhibited varying stages of skeletal maturation at identical chronological ages. In order to examine the relationships of the characteristic changes in rates of growth of various parts of the body, smoothed curves for the semi-annual increments in stature, in the length of the femur and tibia, and in the length of the foot were constructed. (The original data were smoothed twice by the method of moving averages. This

method, recommended for the purpose by Dr. Edith Boyd, in effect emphasized the important general trends while minimizing the less relevant fluctuations.) At present such curves have been made for 70 children whose growth was completed, including all 20 members of the longitudinal series. The similarity of the three curves for each individual was quite striking, particularly when the marked differences in the size of the increments in the three areas were more or less equated by doubling the rate for femur-plus-tibia and by multiplying the rate for the foot by 6, as was done in the two examples shown (fig. 4).

Comparison of the serial growth as shown in these individual records demonstrated certain consistencies. The early-adolescent spurt in rate of growth in the foot, for example, preceded the spurt seen in the long bones and in stature by 6 to 18 months in both boys and girls. Growth in the foot and in the long bones was observed to terminate, on the average, three years after their maximum rates were reached, whereas stature continued to increase for an average of 4.5 years after its "peak" interval was passed.

Children who matured at an earlier-than-average age were found to exhibit their maximal rates in all three areas at a correspondingly early age and, conversely, those who matured late demonstrated delayed periods of maximum growth. In both boys and girls, regardless of the acceleration or retardation of their skeletal maturity, the period of adolescent maximal growth as well as the time of terminal growth were observed to occur in the foot at a younger age than these events occurred in the lower extremity or in stature. Potential aids in estimating the maturity of an individual, therefore, may be found in observations of the shifts in the rates of growth in these three dimensions.

The foot lengthens so slowly and its early-adolescent "spurt" is of such small amplitude that in the growing child it may be difficult to judge the actual 6-month interval of maximum growth. While this discussion may therefore be of more academic than practical value, it does serve to sup-

SEMI-ANNUAL INCREMENTS (SMOOTHED) FOR STATURE, FEMUR & TIBIA, AND FOOT LENGTH
TWO NORMAL SUBJECTS, 1-18 YEARS OF AGE

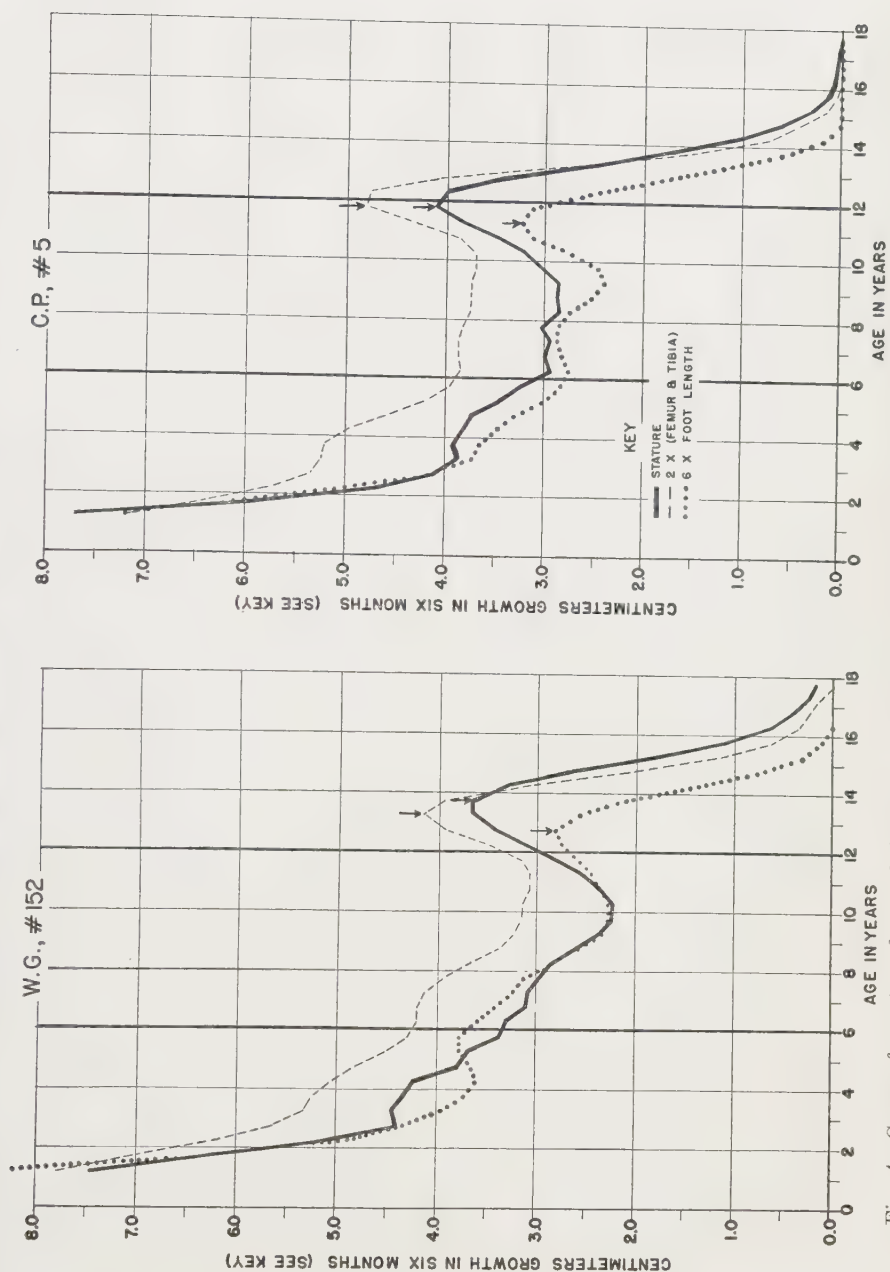


Fig. 4 Curves for rates of growth in stature, the lower extremity and feet show marked similarity when the size of the increments in the three areas is more or less equated. Both the preadolescent "spurt" and the termination of growth occur earlier in the foot, however, than in the long bones or in stature.

port Davenport's observation that the growth of the foot tends to anticipate the adolescent spurt in height (Davenport, '32).

(b) *Per cent mature size attained.* The orderly sequence in the pattern of growth may be further emphasized by recalling that the foot at all ages is relatively closer to its mature length than is either the lower extremity or stature. In the longitudinal series, no data were available after the age of 18 years but for practical purposes the dimensions at age 18 may be taken as representing those of the adult. The relative completion of the growth of each part was therefore computed for each preceding age, using the 18-year dimension as 100%.

The consistently more "mature" size of the foot, especially when it was compared with the relative completion of growth in the femur and tibia, was demonstrated by the average percentages derived in this manner for the children of these series (fig. 5). At one year of age, for example, the feet of girls were already half as long as they ever would be, whereas the same girls did not attain half their mature stature until they were 18 months old and their lower extremities did not attain half their mature length until the age of three. In boys, this same order was true, although the ages were somewhat later; the feet were half-grown at 18 months and height at two years but the femur and tibia not until 4 years of age.

The curve for the relative completion of growth in the foot was essentially parallel to that for stature at all ages until the foot attained its adult length. The curve for the femur-plus-tibia, on the other hand, followed a very different slope since the lower extremity had by far the greatest proportion of growth to achieve between one and 18 years of age. The foot, therefore, does not increase in size in a manner commensurate with that of the extremity to which it is an appendage. Interference with the growth centers of the foot, whether by pathology or surgery, would have proportionately less deforming effect upon final foot length than would similar injury to the growth centers of the femur or tibia

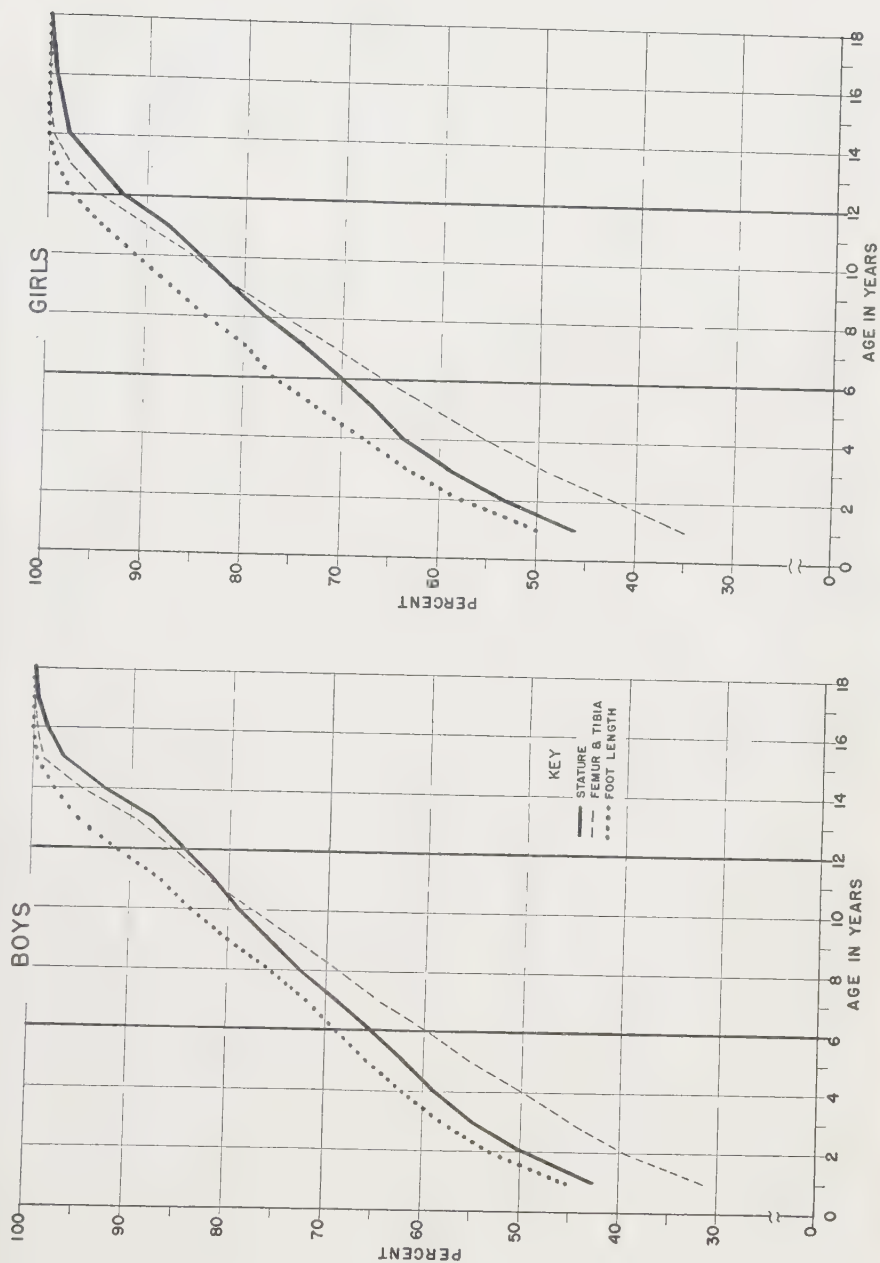


Fig. 5 At all ages, the foot is relatively nearer its mature (18-year) dimension than is the lower extremity or stature.

at the same age. For example, if some factor resulted in the cessation of all growth in one foot of an average 12-year-old boy, that foot would lose approximately 9% of its length and would be one inch shorter than its mate at maturity. If this same hypothetical injury should stop the entire growth of one femur and tibia at the same age, 15% of the length of the lower extremity would be lost and one leg would be 5 inches shorter than the other at maturity.

(c) *Changing relationships with age: foot, lower extremity, and stature.* Since in the young child the lower extremity was proportionately so much smaller relative to its adult size than was either the foot or stature, it was to be expected that the ratios between the absolute lengths of these three areas would change markedly in the years preceding adolescence. To illustrate such shifts in proportions, the 20 children of the longitudinal series were used. At each age, individual roentgenographic measurements of the foot and of the femur and tibia were related to one another and to the child's height (table 3). The length of the foot was measured from the heel to the tip of the great toe with the correction factor applied as described above. The length of the two long bones included the ossified portion of both the proximal and distal epiphyses as well as the diaphyseal lengths.

The values for the ratio of the foot to the tibia which were obtained by this method of measuring showed a continuous decrease from one year of age until the tibia had achieved its mature size although all the figures were higher than those reported by others (Davenport, '32; and Straus, '27). In all but 4 individuals of this series, for example, the foot was found to be actually longer than the measured length of the tibia at one year of age, the average index being 103% at this age level. The proportionately greater growth of the tibia in the following years resulted in a rapid drop in the ratio so that the adult length of the foot in the same individuals averaged only 72% of the final tibial length. Half this decrease had taken place before the age of 5 in both boys and girls and three-quarters of it had occurred by 10 or 11 years of age.

The range of variation in this ratio at each age was large, the average standard deviation being 4.1 for boys and 4.6 for girls, so that the small decrease in the ratio which occurred following the ages of 9 or 10 years in girls and 11 years in boys was not statistically significant.

TABLE 3

Changing relationships of foot,¹ long bones,² and stature according to age and sex
Mean ratios derived from longitudinal series—10 boys and 10 girls

AGE	FOOT: TIBIA		FEMUR + TIBIA: STATURE		FOOT: STATURE	
	Girls	Boys	Girls	Boys	Girls	Boys
	%	%	%	%	%	%
1	102.9	102.5	34.4	34.6	15.9	15.9
2	96.6	95.6	37.9	37.2	16.1	15.8
3	93.0	91.5	39.2	39.3	16.1	15.9
4	89.8	87.6	40.7	40.7	16.0	15.7
5	86.1	83.8	42.7	42.6	16.1	15.7
6	84.0	82.6	43.5	43.5	16.0	15.7
7	82.0	81.0	44.5	44.5	16.0	15.7
8	80.2	79.4	45.2	45.4	15.9	15.8
9	78.8	78.1	46.1	46.2	16.0	15.8
10	76.9	77.2	46.9	46.8	15.9	15.9
11	76.2	76.4	47.4	47.6	15.9	15.9
12	75.1	75.6	47.8	48.2	15.8	16.1
13	73.9	74.4	48.1	48.6	15.5	16.0
14	72.6	72.6	47.9	48.8	15.3	15.6
15	72.5	71.3	47.8	48.6	15.2	15.3
16	72.4	71.1	47.7	48.3	15.1	15.1
17	72.4	71.2	47.5	48.0	15.1	15.0
18	72.4	71.2	47.4	47.7	15.1	14.9

¹ Length of foot measured from lateral roentgenograms multiplied by correction factor, 0.9741.

² Length of long bones measured from orthoroentgenograms, ossified portion of both epiphyses included.

The proportion of femur-plus-tibia to stature which was roughly the inverse of the better known "crown-rump: crown-heel" ratio, increased among these children from 34% at one year of age to a maximum of 48%. The femur and tibia represented a slightly decreasing proportion of total body

length after this maximum which was ordinarily attained two years before the cessation of growth in the lower extremities. These shifts demonstrated the more rapid growth of the lower extremity compared to that of the trunk during infancy and childhood as well as the continued slow growth of the trunk after the long bones had essentially completed their growth. The changes in the ratio of femur-plus-tibia to stature were less rapid but were within a narrower range of variation than those in the Foot:Tibia index. The average standard deviation was much smaller, 1.0 for boys and 1.4 for girls, so that the yearly changes were actually of higher statistical significance over the span from one through 10 years of age than were the larger changes seen in the ratio of the foot to the tibia.

The relation of the length of the foot to stature showed little change with increasing age. In both boys and girls, the length of the foot consistently represented about 16% of stature, with a range at each age of less than 2%. The difference between successive mean ratios was negligible from one to 14 years in girls and from one to 16 in boys. Following these ages, however, a small but significant decrease was noted in the mean values due to the fact that active growth had ceased in the foot while stature continued to show an appreciable increase.

These trends, derived from 20 individual records, were confirmed by analysis of the larger, more cross-sectional series. When the ratios were computed on the latter group using the average lengths of the foot, of the femur and tibia, and of stature at each age, almost identical values are obtained to those described in table 3.

All three of these proportions may be helpful in describing the differences between individuals since the ratios varied from child to child and since each child tended to keep the same standing in relation to the group at all ages. The consistent changes in the ratios from age to age might also be helpful in assessing the progress of an individual toward maturity. They are reliable for this purpose at the different

intervals during which the degree of change in the size of the ratio is statistically significant. The ratio of foot to stature, for example, would be useful in this regard only in late adolescence after the foot had stopped growing. On the other hand, the other two ratios showed changes of such significance only during the interval from infancy to the age of 9 years in girls and 11 years in boys.

Proportions of the foot

We were particularly concerned with whether or not there was a shift in the relative contributions of certain parts of the foot at particular ages; whether, for example, the heel segment would exhibit a relatively greater proportion at one age than another. Straus ('27) has reported that the proportion of the os calcis to total foot length in prepared anatomical specimens increased from 28% in the newborn to 35% in adulthood and the impression of an increasing proportion of the heel area in the young child is also gained from visual observation. Davenport ('32) on the other hand, using serial anthropometric measurements found that the relative heel length decreased from 30% to 22% among boys between the ages of 7 and 16 years.

The average ratio of "heel" to total foot length changed little with age in the longitudinal series of 20 subjects studied here; neither of the trends described above was evident in these roentgenographic data. Our initial measurements, which were based upon the length of the ossified portion of the os calcis alone, did appear to demonstrate a more rapid growth of the heel particularly during the first 5 years of life (table 4) but this change was found to be primarily a reflection of the increasing calcification of the posterior portion of the bone.

For practical purposes, the proportions of the foot as measured from the landmarks chosen on these roentgenograms may be said to be stable throughout the years of

growth, individual variation being a stronger factor than the changes in proportion which occurred with age. The relative amounts of total foot length contributed by the mid-tarsal segment (cuboid), by the metatarsal segment, as well as by the heel were very similar throughout the growing years (table 4). Although there were some changes, they were not found to be statistically significant except in the relation of the mid-tarsus to total foot length (Blais and

TABLE 4

Proportions of the human foot, 1 to 18 years

Means derived from longitudinal series, 10 boys, 10 girls

“Heel,” mid-tarsus and metatarsus related to total foot length as measured from lateral roentgenograms of the foot

MEANS, 10 BOYS				AGE	MEANS, 10 GIRLS			
CALCIFIED OS CALCIS	“Heel” ¹	Cuboid ²	Meta- tarsus ³		CALCIFIED OS CALCIS	“Heel” ¹	Cuboid ²	Meta- tarsus ³
%	%	%	%		%	%	%	%
21.5	32.2	13.9	15.3	1	22.6	32.1	13.7	16.5
23.9	33.1	14.3	16.1	2	24.3	32.7	14.0	16.7
25.2	33.4	14.2	15.5	3	25.4	32.6	13.8	16.3
26.4	33.7	14.2	15.9	4	26.0	32.6	13.8	16.3
27.1	34.0	14.3	15.8	5	26.1	32.4	13.6	17.0
27.2	33.6	14.2	16.0	6	26.3	32.3	13.6	16.9
27.3	33.3	14.1	16.0	7	26.6	32.2	13.6	16.7
27.4	33.1	14.0	15.8	8	27.3	32.4	13.4	16.6
27.8	33.0	13.7	15.6	9	27.6	32.3	13.1	16.6
28.2	33.1	13.5	15.4	10	28.2	32.4	13.0	16.8
28.5	33.2	13.3	15.3	11	28.5	32.3	12.4	16.8
28.9	33.2	13.1	15.2	12	28.6	32.5	12.3	17.1
29.3	33.3	12.9	15.3	13	28.7	32.6	12.1	17.0
29.7	33.7	12.7	15.6	14	28.9	32.6	12.1	17.2
30.1	33.8	12.5	16.3	15	28.9	32.7	12.1	17.2
30.1	33.5	12.5	16.6	16	29.0	32.8	12.1	17.2
30.3	33.4	12.5	16.6	17	28.9	32.8	12.1	17.2
30.2	33.4	12.5	16.6	18	28.9	32.8	12.1	17.2

¹ Skin at back heel to mid-point between os calcis and cuboid.

² Mid-point between os calcis and cuboid to mid-point between cuboid and fourth metatarsal.

³ Mid-point between cuboid and fourth metatarsal to distal epiphyseal line of fifth metatarsal.

Green, in prep.). During the last 5 years of growth, for example, this mid-tarsal area was found to contribute but an inconsequential linear increment to the total length of the foot.

SUMMARY

The growth of the normal foot from one to 18 years of age has been described for boys and girls. Measurements from 532 subjects of two series which were distinctly longitudinal in nature not only provided distributions for the lengths of the foot attained at each age but also permitted the expression of the yearly increase in length throughout the interval.

The changing inter-relationships of the foot, the lower extremity, and stature as well as the changing rates of growth in these areas from one age to another were defined for the child from one through 18 years of age. The foot was found to grow in synchrony with the body as a whole rather than with the lower extremity of which it is a part: the length from heel to toe maintained the same relationship to the length from heel to head at all ages during which the foot was increasing in size. In general, the early-adolescent spurt in the rate of growth in the foot preceded that in the long bones and in stature by 6 to 18 months; growth in the foot and the long bones tended to terminate three years after their maximum rates were reached, whereas stature continued to increase for an average of 4.5 years after its "peak" interval. Cessation of growth, then, occurred first in the foot, next in the long bones, and last in stature.

The proportionate contributions to total foot length of three segments, the heel, the mid-tarsus and the metatarsus, were analyzed from a small longitudinal series of lateral roentgenograms of the foot. In this series these segments did not change in their relation to the whole to any practical degree throughout the years of growth.

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VIKING FUND MEDALIST FOR 1955

The Viking Fund Medals and Awards for 1955, given by the Wenner-Gren Foundation for Anthropological Research, were presented at a dinner at the Waldorf Astoria on March 2, 1956. Dr. Sherwood L. Washburn was toastmaster and, in Dr. Wenner-Gren's absence, Dr. Paul Fejos represented the Foundation. The nominee for the award in physical anthropology was presented by the president, as follows:

Professor Sir Wilfrid Edward Le Gros Clark, F.R.S., of England is nominated by the American Association of Physical Anthropologists to receive the Viking Fund Medal and Award in Physical Anthropology for 1955. This is the first time that a foreign scientist has been chosen by this Association.

Sir Wilfrid qualified in medicine at St. Thomas's Hospital Medical School, in 1916, and served in the Royal Army Medical Corps in World War I. Immediately, thereafter, he returned to St. Thomas's as demonstrator in anatomy for 2 years. Then followed his appointment as principal medical officer of Sarawak, Borneo for 3 years. During this period he made expeditions up-country and collected primates, in particular *Tarsius* and *Tupaia*. Studies developed from these collections which laid the foundations for his critical judgment in the phylogenetic interpretation of fossils and their relation to hominid genera.

On his return to England and anatomy he accepted a readership at St. Bartholomew's Hospital Medical School and in 1927 the chair of anatomy. Thus, there was early recognition of Sir Wilfrid's leadership in the field of anatomy. He transferred to the chair of anatomy at St. Thomas's, his alma mater,

Viking Fund Medalist for 1955



WILFRID EDWARD LE GROS CLARK

in 1929 and 5 years later accepted the position he has continued to fill, that of Dr. Lee's Professor of Anatomy at Oxford University.

Additional responsibilities have been many. To mention a few: he was president of the Anthropology Section of the British Association for the Advancement of Science in 1939; he has been director of the Medical Research Council Unit of Climate and Working Efficiency since 1948; he has served as vice-president of the Zoological Society and of the Royal Anthropological Institute; he has been a member of the Medical Research Council; he has been Hunterian Professor of the Royal College of Surgeons, first in 1934 and again in 1945; he was editor of the *Journal of Anatomy* for a 6-year period in the forties; and president of the International Anatomical Congress in 1950. The Congress met at Oxford and Sir Wilfrid proved to be as hospitable a host as he was efficient as a president. Rather different from these responsibilities, which developed from his place in science, was his election in 1955 as Master of the Worshipful Company of Salters of London. Sir Wilfrid's connection with the Salters Company is an hereditary one which may be traced back to 1736; in these days the company finances the "Salters Institute of Industrial Chemistry" and thus Sir Wilfrid supervises the operation of this Institute.

His membership in scientific societies extends beyond the British Isles, to Buenos Aires, to France, to New Zealand, to Norway and to Sweden. He was elected to the Fellowship of the Royal Society in 1935. Honorary degrees have been accumulating. Last year his distinction was recognized in Great Britain when he was knighted by Her Majesty, the Queen.

Sir Wilfrid's contributions to biological science have been many and varied. His book, *The Tissues of the Body*, now in its third edition, is a most helpful and erudite introduction to the study of anatomy. He is aware of the part proper terminology plays in avoiding confusion in scientific writing and has set an example of clear meaning in his own writings.

His early interest in Primatology and Human Paleontology led him into both analytical and experimental researches on different parts of the skeleton, particularly the skull; on growth and regeneration of muscle fibers; and, most especially, on the structure and connections of the brain and its parts. His researches on the structure of the Primate thalamus and hypothalamus and on the lamination of the lateral geniculate body are now classics. From his anatomical studies a dynamic conception of the lines of evolution pertaining particularly to the species, *Homo sapiens*, has resulted. Two general principles have been followed in his formulation of this progressive concept: one, "In the absence of an abundant fossil record, conclusions regarding lines of phylogenetic development must always be provisional; and, as the evidence accrues with new discoveries, they will need constant revision." (*The Fossil Evidence for Human Evolution*, Chicago, 1955, p. 46). Symbolic of this principle is the significant part Sir Wilfrid played in re-evaluating the Piltdown fragments and in exposing their fraudulent character. The second principle is "... that, in assessing the taxonomic position of a fossil specimen, account must be taken of the total morphological pattern (and not its individual units) ..." (*op. cit.*, p. 47). He has applied this principle most effectively to the Australopithecines, the status of which he has done much to elucidate, since his first visit to South Africa in 1946.

His book, *Early Forerunners of Man*, was published in 1934 and is still one of the best books on the subject. His widely read and useful British Museum Handbook, *History of the Primates*, now in the 4th edition, first appeared in 1949. It was recognized immediately by Hooton as "... a brief and wholly admirable treatment of the entire subject of Primate evolution and the emergence of man as shown by fossil evidence," and, it was strongly recommended, "... because Professor Le Gros Clark is so careful not to go beyond the evidence." (*Am. J. Phys. Anthropol.*, n.s. 8: 127, '50.) Last year, *The Fossil Evidence of Human Evolution, an Introduction to the Study of Paleoanthropology* was published by the

University of Chicago Press as one of the series of "The Scientist's Library: Biology and Medicine." The contributors to this series have been asked to provide authoritative information about the growth and status of the assigned subject in such a fashion that the book may be read with profit not only by the specialist but also by those whose interests lie in other fields. This difficult task Sir Wilfrid accomplished with distinction.

Doctor Washburn, Dr. Fejos, Ladies and Gentleman, on behalf of the American Association of Physical Anthropologists I have the honor to present, with great pleasure and pride, Professor Sir Wilfrid Le Gros Clark for the Viking Fund Medal and Award in recognition of his long and distinguished series of contributions to primatology and human paleontology.

MILDRED TROTTER

P. B. CANDELA

1906-1956



Pompeo Benjamin Candela was born in Brooklyn on July 31, 1906, the son of Italian parents. He attended Columbia University, Long Island College of Medicine, and received his M.D. in Rome in 1929. He was a practicing physician and surgeon in Brooklyn 1930-1942, and in California from 1947 on.

Doctor Candela was very much interested in research. He never had the good fortune to occupy an academic chair, but a man with his interest and energy could not be stopped by this. In the evenings, after his patients had gone, Doctor

Candela retired to the kitchen, put drops of serums into test tubes containing bits of ancient tissue, and proceeded to make a name for himself in science. He successfully adapted to the testing of ancient bone the technic of Boyd and Boyd for determining the blood groups of mummified muscle. Some anthropologists and serologists apparently felt this was carrying an already dubious thing to extremes, and I myself (it seems most ungracious in retrospect) expressed some scepticism. Doctor Candela stuck to his guns; he invited us to send him bones of known blood group, marked in a code known only to us. This was done. Candela found two of the eleven specimens unsuitable for testing, but he determined correctly the blood group of each of the remaining nine. There could be no doubt about it, Doctor Candela's methods worked. Although it has not become, and may never become, a simple task to determine the blood groups from bone, anthropology and legal medicine alike are continuing to benefit from this discovery.

Candela then proceeded to write a really epoch-making paper (which at least one editor summarily rejected, but which was finally published) in which he attempted to demonstrate that the amounts of blood group gene B found in various European populations were introduced by Mongol invaders during the 5th to 15th centuries. If we no longer believe that quite all of the B in Europe is of origin as recent as this, it is because of more recent discoveries which however probably do not invalidate the general truth of Candela's thesis.

In collaboration with Dr. A. S. Wiener and independently, Candela also did important basic work on the serology of the primates. These studies on lower primates, whose red cells failed to react with anti-A and anti-A serums, were concerned with the problems why the serum of such monkeys did not always contain anti-A and anti-B, but instead some serums contained anti-A, others anti-B and still others neither. The reason was found to be that Landsteiner's rule applied to monkeys, and monkeys not having anti-A in their serum had A blood group substance, only in the salivary glands and other organs and not in the red cells. In more recent years Candela

was occupying himself with the morphology of human and primate hair. He was also active in many other ways. Shortly before his death he was Director of the Kern Valley Community Hospital in Wafford Heights, California, and Chairman of the Cloud Seeding Committee there.

Doctor Candela died on January 6, 1956 from hypertension with renal and cardiac complications. His death was a loss to anthropology, but his career, in some ways a typical American success story, will continue to be an inspiration. It is sad that he was never free to devote his full energies to research in his chosen field, and doubly sad that his life ended at an age we are not nowadays inclined to consider advanced.

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BRIEF COMMUNICATION

THE PRE-MOUSTERIAN HUMAN MANDIBLE FROM MONTMAURIN

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TWO FIGURES

The Montmaurin mandible, dating either from the Riss-Würm, or possibly the Mindel-Riss, interglacial, is of Neanderthaloid morphology in the main, but in certain points of detail is closer to the Mauer jaw. Smaller but at the same time more massive than the mandibles of the true Neanderthals, it doubtless belonged to an individual of the Preneanderthaloid type. The mandible, which now belongs to the Musée de l'Homme in Paris, is in excellent condition. It is less voluminous than those of most human groups, modern or fossil, but is even more striking because of its robustness and the retreating chinless profile of the symphysis.

Site. The mandible was found in 1949 by R. Cammas in the lower part of a vertical gallery in the cave system of Montmaurin (Haute-Garonne). This deep cave is known as the Grotte du Coupe Gorge, one of the four sites comprising the Montmaurin complex, situated in the Seygouade Valley some 13 kilometers (ca. 8 miles) north of Saint-Gaudens (Haute-Garonne).¹

¹ For additional information see Baylac, Cammas, Delaplace, Lacombe, Laplace-Jaureteche, Méroc, Mothe, Simonnet and Trouette: "Découvertes récentes dans les Grottes de Montmaurin (Haute-Garonne)," *L'Anthropologie*, t. 54, no. 3-4 (1950) pp. 262-271; L. Méroc: "X^e Circonscription préhistorique," *Gallia*, t. 5, fasc. 1 (1947) pp. 193-194; t. 6, fasc. 2 (1948) pp. 409-412 (fig.); t. 10, fasc. 1 (1952) p. 93; t. 12, fasc. 1 (1954) pp. 109-111; also, H. Vallois, 1955, "La mandibule humaine pré-moustérienne de Montmaurin," *Comptes Rendus des Séances de l'Académie des Sciences*, vol. 240, pp. 1577-1579.

Associations. The deposit in the gallery contained a warm fauna, with a pre-Mousterian type of industry. The great depth at which the jaw was found and its extreme degree of fossilization (density = 2.68) leave no room for doubt as to its contemporaneity with the associated industry and fauna, nor as to its dating to an interglacial period — either of Riss Würm, or possibly of Mindel-Riss age. It is therefore older than the classic Neanderthaloids, and is the oldest specimen of its kind known in France. In the whole of Europe, in fact, only the Mauer jaw is older.

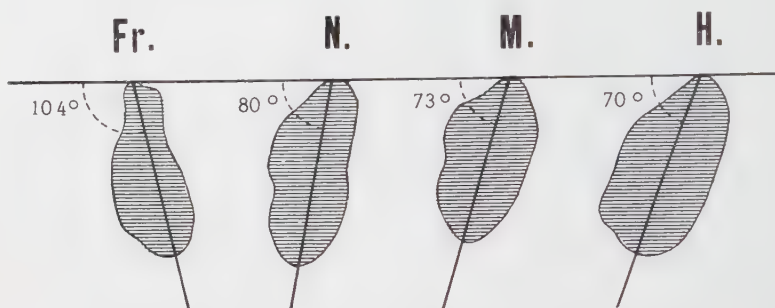


Fig. 1 Inclination angles of: Fr = a Frenchman, N = Neanderthal Man, M = Montmaurin, H = Mauer. The sections are in the midline of the chin, with the anterior surface to the right.

Horizontal ramus. This is very thick, with an index of robusticity of 58.6, which is identical with that of Mauer and higher than those of almost all Neanderthaloids. The outer surface is markedly bulging behind the mental foramen. The lower edge is broad, with a marked posterior marginal tubercle. On the inner surface, the area just below the mylohyoid ridge is raised and there is no trace of a sublingual fossa. The mental foramen is double, as it is in 62.5% of Neanderthal specimens.

Symphysal region. The symphysis looks extremely primitive. The symphyseal angle is 101° while that between the anterior symphyseal surface and the plane of the lower borders of the horizontal rami is 105° . These figures are almost identical with those of the Mauer jaw and higher than those

of most Neanderthaloids. As in the Mauer specimen, the symphysial profile is retreating and shows no projection. The upper part of the inner surface slopes strongly backward forming an angle of 33° with the alveolar plane. Below this there is first a well-developed torus, and then a hollow area in the midst of which an oblong projection takes the place of the



Fig. 2 The Pre-Mousterian Human Mandible from Montmaurin (Haute-Garonne).

genial tubercles. The surfaces of attachment of digastric muscles begin on the lower border of the bone and extend around onto the outer surface to a point just below the first molar. All these features recall either Neanderthal morphology or that of Mauer, but more often the latter.

Ascending ramus. The ascending rami are less wide than those of Mauer Man but of the same breadth as in Neanderthals, and, as in both of these types, the index (64.7) is higher

than in modern man. The mandibular angle is of the order typical of fossil man: it is relatively small, 110° , and the gonial angles are evenly rounded off. There is marked relief on both surfaces of the ascending rami: on the outer surface is a well-developed *torus obliquus* while on the inner side the lower extremity of the *torus triangularis* merges with the alveolar ridge. The mylo-hyoid groove is partly closed over. All these characters are reminiscent of Neanderthal Man in particular.

The condyles are longer and wider than in modern man, and their long axes are set at an angle of only 16.5° with the frontal plane. The articular surfaces are oval as seen from above, as they are in Mauer Man, and not flattened as in Neanderthal. As in both Neanderthal and Mauer, the lateral projection of the condyles is marked. The sigmoid notch is more pronounced than in the Mauer specimen but less so than in the Neanderthals.

Dentition. The sides of the dental arch are markedly divergent toward the rear. The only teeth preserved, the molars, show a striking complex of archaic characters. The second molar is a little smaller than the first, but the third is the longest of all and has the unusual nodule of 106. In all three, the mesio-distal diameter exceeds bucco-lingual breadth. There is no cingulum, but all the crowns show the *Dryopithecus* pattern and there is, in addition, a small hypoconulid and a *tuberculum sextum*. Some wrinkling is present, especially on the third molars. The pulp cavities are moderately taurodont.

Discussion. Thus the Montmaurin mandible presents a combination of characters that places it alongside those of both Neanderthal and Mauer. Its overall morphology is closer to that of the former, while in certain details it is more like the latter. An examination of the dentition confirms its primitive character.

In a previous paper,² I have shown that two main human types were coexistent in pre-Würmian times, the Preneander-

² Vallois, H. 1949 "L'Origine de l'Homo sapiens." *Comptes rendus des séances de l'Académie des Sciences*, vol. 228, no. 11, pp. 949-951.

thal and the Presapiens. Until now we have known nothing of the mandibles of either. By its general characteristics the Montmaurin jaw seems to have belonged to a Preneanderthal. It shows us that this type, while more generalized than the Neanderthaloids proper in its cranial morphology, had a distinctly more archaic mandible.

REVIEWS

THE STONE AGE RACES OF NORTHWEST AFRICA. By L. Cabot Briggs. 90 pp. Illus., Bull. 18, American School of Prehistoric Research, Peabody Museum, Harvard University, 1955. \$3.00.

Lloyd Cabot Briggs has compiled an excellent and readable report on the ancient peoples of Northwest Africa which appears as a well published and amply illustrated bulletin of the American School of Prehistoric Research. Dedicated appropriately to the memory of the late Earnest Albert Hooton and the venerable Henri Victor Vallois, Doctor Briggs has done the tremendous job of bringing together in one study all available data on the human skulls of known clear-cut documentation from Northwest Africa (Northwest Africa being that section of Africa west of Libya and Tunisia and south to the limits of the Sahara desert). The race history of this strategic corner of Africa is revealed essentially from three Pleistocene fragments plus a large representative group of 56 Mesolithic and 7 Neolithic skulls derived from 66 excavations which have been done in the area over the past 100 years.

As a result of the detailed presentation of data and an organization designed to give historical connections, we have here another fine monograph in a growing series of studies by the American School of Prehistoric Research. For instance, in the section entitled "Historical and Archaeological Summary," Briggs has included a wealth of detailed archaeological background for the human remains so associated and described in this monograph. Many sites have difficult Arabic French names, but he has *clearly* presented the all important facts of stratigraphy and association so his reader can follow the sequence of racial types with full confidence.

Fragments of only three individuals are of Paleolithic (Pleistocene) age. The Rabat find from the Atlantic coast and the Tangier specimens (two individuals), described by Senyurek, suggest Neanderthal-like people. A footnote mentions the newly found lower jaws (Ternifine) found near Mascara 75 miles east from Oran, Morocco, representing a very primitive human type somewhat similar to Pithecanthropus.

All the Mesolithic skulls are strictly modern (*sapiens*) in type and represent a very mixed population judging from the variability. For

comparative series he uses published data from Afalou, Guanches, Canary Islands, Ancient Greeks, Early Kentucky and the Pecos Pueblo Indians. Some critics may not approve of these comparisons and Briggs' methodology. He used them partly from necessity of finding adequate data similar in time, space and/or ecological limits.

Most of this report (55 pages) is devoted to the thorough description of 56 skulls of Mesolithic age which Briggs has classified into 4 morphological types. Type A, called "Palaemediterranean," are perhaps the earliest Northwest African sapiens human beings—a long headed strain equivalent to Combe Capelle. Type B, named "African Mediterranean," possibly of Near East origin, appears to have some "Bosopoid" traits. Type C, called "African Alpine," is a brachycephalic group. Type D is a mixture which occurred locally between the "African Mediterranean" and "Alpines." This is a curiously varying group and is perhaps most like the Hotu People of northern Iran.

The Neolithic remains consist of only 7 individuals, 5 typed as a northern series and said to be the result of a stabilized mixed-group containing some Negro admixture. The remaining two are a southern negroid type resembling the "Hamitic" strain presently found in the modern Fulah, an old (5,000 years) racial type originating in East Africa.

In a final chapter, Doctor Briggs describes the occurrence of abnormal conditions. Apparently the Mesolithic series, particularly the African Mediterraneans, went all out for tooth evulsion, among children between the ages of 8 and 11 years. He reports incision of the parietal bones of one female victim. Only 4 skulls show any sort of bone lesions, including an Afalou skull with a broken left nasal bone. Mild osteoporosis of frequent occurrence but confined more or less to the bones of the vault and on the rounded surfaces of the brow ridges and Briggs suggests that Vitamin D deficiency may be responsible. Curiously enough, the people who live either on or near the coast have the highest incidence of dental caries, susceptibility to alveolar abscess and necrosis, as well as osteoporosis.

All students interested in the study of African prehistory will find this monograph an important reference. It does for Northwest Africa what Leakey's "*Stone Age Races of East Africa*" does for that other section of the continent. All the primary data are preserved on microfilm and available from the Peabody Museum.

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RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE KNEE. A STANDARD OF REFERENCE. By S. Idell Pyle and Normand L. Hoerr. viii + 82 pp., Illus. Charles C Thomas Publisher, Springfield, Illinois, 1955. \$4.25.

For 30 years, clinical assessments of "skeletal age" have been based on the number of centers, degree of modeling, and extent of epiphysial union in the hand and wrist. Other systems involving several arm and leg joints have been proposed, but have not come into common use because they require a larger number of x rays. The present book extends the pioneering work of Flory and Todd, and the more sophisticated Greulich-Pyle system, to the knee, and it merits all of the usual reviewers' approbations by being timely, useful, well-printed, authoritative and so on.

The method of selection of the "standards" deserves a certain amount of comment, for Pyle and Hoerr follow Todd's original plan of showing optimal norms based on well-above-average healthy white children. From 4,483 "carefully selected" Cleveland Children, those showing "essentially negative medical histories . . . who had been enrolled in the study for the longest term of years" were selected, and the sum further reduced to a workable 100 boys and 100 girls (with some further exclusions). The corresponding x-rays were studied "backward," to determine when particular osseous markings first appeared, and again "forward." The final standards with separate age equivalents for boys and girls respectively, were derived from "cross-sectional anatomical modes" and "chronological age-limited medians."

Special attention is given to the technique of selection, for it is an unusual one. Most developmental norms are based on a mixture of the well and the near-well excluding only those too sick at the moment to be measured. The net difference in this case, should be slight however, since minor and subclinical debilities apparently do not result in uniformly delayed skeletal ossification. And the selection of the 50th film arranged in order of development, for a given age level, should be acceptable to those concerned with skewness. But the final standards, where a given developmental stage is given an age-equivalent of 18 years 4 months for boys and 14 years 9 months for girls (to select one example) may bother some users. Essentially there is a double standard, the films here reproduced constitute the medians for the boys at 1, 6, 9 and 11 months, and half yearly until 6, and yearly thereafter, and the female age equivalents are more or less interpolated.

The standards could have been set up in other ways. Certainly more information on variability is desired. The reviewer wishes that,

for each standard, the percentage of children attaining a comparable stage of development at different ages, had been given. Then we could T-score or Z-score individual knee ratings instead of just saying that at 12 years 0 months Willie had a Pyle-Hoerr skeletal age of 10 years 0 months.

But Doctors Pyle and Hoerr do state "the standards in this atlas, . . . if our reasoning is correct, if our methods are trustworthy, and if our judgment is adequate, are the most representative of the levels of development attained by the children in our Research Series."

No exception can be taken to this statement and we are confident that they have performed this extremely laborious task ably and well.

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THE PHYSICAL ANTHROPOLOGY OF IRELAND. By Earnest A. Hooton and C. Wesley Dupertuis. WITH A SECTION ON THE WEST COAST IRISH FEMALES. By Helen Dawson. No. 1, Text, pp. xix + 304; No. 2, Tables and Half-tones. Papers of the Peabody Museum of Archeology and Ethnology, Harvard University, Vol. 30, 1955. \$10 (cloth, \$13).

One hardly knows how to begin a review of this large, complex work comprising one volume of 510 tables and 47 half-tones, and another of detailed analyses in text and figures. Perhaps it may be well to begin with some words on the scope, method, and results, especially as these pertain to Ireland, and then consider the broader implications of the content.

The field work was initiated in 1934 and extended over a period of about two years. Measurements, morphological observations, and data on education, language spoken, and occupation, were obtained on some 10,000 men by Doctor Dupertuis in 426 villages and towns in all 32 counties of Ireland. Like material was obtained on nearly 2,000 Irish women by Doctor Dawson. The late Professor Hooton was responsible for the organization and interpretation of the material as a whole. The work is divided into 4 major parts. Part I, "Catholics by County Subgroups," compares the sociological data, measurements and indices, and morphological observations, among the several counties with predominantly Catholic populations and also by groups of these counties or "geo-ethnographical regions." Part II is a "Comparison of Catholics and Protestants." In Part III, a long section titled "Morphological (Subracial) Types," the material is sorted on

the basis of hair color, cephalic index, and eye color, and secondarily on occasion by the additional factors of nasal index and stature. By this sorting method (initially devised in about 1930 for "dividing up American criminals then being studied, into subracial or ethnic types"), the total male series was divided into 8 "subracial types," namely, Nordic Mediterranean (28.9%), Keltic (25.3%), Dinaric (18.6%), Nordic Alpine (18.4%), Predominantly Nordic (6.8%), East Baltic (1.1%), Pure Nordic (0.6%), Pure Mediterranean (0.3%). These "types" are compared one with the other with regard to all the sociological, anthropometric, and morphological observations at hand, and in turn are correlated with archeological finds; with legendary, historical and linguistic data; with historical events and conquests; and the like. Part IV is a detailed analysis of the Irish females more or less following the male pattern, but providing in addition a valuable summary of male vs. female comparisons for each character.

As regards Ireland, the sum of the diverse analyses seems to be that "... in both Ireland and Wales the proportionately strongest morphological type is what we call Nordic Mediterranean — long-heads with dark hair and mixed eyes. This seems to be the fundamental type of the British Isles. It probably incorporates in both countries the bulk of the descendants of Paleolithic settlers (present in Britain only), of the Mesolithic inhabitants, of the Neolithic and Megalithic peoples, with some reinforcement from later comers. The morphological type second in strength in both countries is what we have called the Keltic type — long-headed with pure light eyes" (p. 235). And, "We can be certain that the Norman conquest introduced no sub-racial or morphological types that were not already represented in the population, and the same can be said of further colonization by the English and whoever else arrived subsequently in sufficient force of numbers to count in the present day population of Ireland" (p. 223). It should also perhaps be noted at this point that Doctor Hooton takes sharp issue with Professor Carleton S. Coon's interpretation of the present Irish data in the latter's book "The Races of Man" (Coon, '39). "The principal point at issue is Coon's hypothesis of the 'survival' or 'reemergence of Upper Palaeolithic' types. . . ." in Ireland, a position which Professor Hooton finds untenable (p. 239).

There can be little question about the logic of the above conclusions on the basis of the given evidence. What may be questioned, it seems to me, are some of the methods pursued and statements made in the

study. Thus, after 16 large double-column pages of text, one finds that (p. 120) :

Anyone who has read carefully the foregoing attempt at dividing Ireland into geo-ethnological areas will conclude that the areas thus delimited are, in nearly every instance, composed of county blocks which do not cohere anthropologically in any satisfactory way. In other words, the attempt was a failure.

Professor Hooton's intellectual honesty is refreshing, but why publish what in effect are work-sheets?

Even though in Ireland the religious groups are largely equivalent to geographical entities — Protestants in the North and Catholics in the South — the comparison of Irishmen on the basis of religious affiliation seems to me of dubious merit. Doctor Hooton himself apparently had some qualms about this procedure, for in comparing hair-form of Protestants and Catholics he notes, "Every grade of curved hair is more heavily represented in the latter [Catholics], but especially low-waved and deep-waved hair. The differences are ethnic and regional rather than religious, of course." Why the subdivisions by religion, then? This uncritical tendency to associate sociological phenomena with physical characters occurs elsewhere in the report, e.g. an attempt to relate extent of illiteracy with "subracial types," i.e. Pure Nordic, Predominantly Nordic, East Baltic, and the like (p. 149). As a matter of fact, by and large the Irish men are found to be a pretty homogeneous lot metrically and morphologically. One indication of this circumstance is the fine subdivisions resorted to in order to obtain "differences" among them. For example, mean stature in the counties ranged between 170 and 174.9 cm and was divided into 5 categories of 1 cm intervals; mean head length and mean head breadth were divided in 5 and 4 groups of 1 mm intervals; mean cephalic index is divided in 6 groups (77.5 to 80.4) by *one-half* index point intervals.

Apparently more persons with dark eyes, dark skins, curved varieties of hair, and pigmented moles, were found in the young than among the old in the present male series. Doctor Hooton explains this peculiar situation by postulating a theory of "selective survival of light-eyed persons and of progressive elimination of dark-eyed persons throughout the older age groups," although, "Of course, this explanation raises the presumption that most of the dark-eyed Irish either die early in life or marry light-eyed mates and leave only mixed-eye progeny" (p. 201). Professor Hooton refers one to a previous publication for a more extensive treatment of the subject of age and "selective survival" in the Irish (Hooton and Dupertuis, '51). Going to the latter, one finds that Professor Hooton recognized the pitfalls

of his position, and states: "Almost none of these curious age regressions shows, in the case of the age surviving and predominating variation, a simple and obvious advantage that would make for a favorable selection of its possessor. Thus we can see no reason why a dolichocephal should more easily and prematurely enter the Kingdom of Heaven than a brachycephal. . . . If a morphological or a metrical variation has some survival advantage, it is probably because it is linked to some physiological or other constitutional variant not quickly apparent, but in reality the causative factor in the situation" (Hooton and Dupertuis, '51, p. 127).

Not a shred of evidence is given for the above concept. Professor Hooton himself candidly admits in the earlier report that his views on the matter were purely speculative, that "Often this [assignment of a trait to age change or to selection] amounts to a mere guess based upon sheer ignorance" (p. 129). In this regard, also, as tabulated below, the female series does not show the aforementioned age differences in hair color or eye color, or to any considerable extent even in prevalence of straight compared with wavy hair, or occurrence of moles (tables XXXI-4, 5, 10, 11; pages in the volume of tables are not numbered).

AGE	HAIR COLOR: PER CENT			EYE COLOR: PER CENT		HAIR: PER CENT STRAIGHT	MOLES: PER CENT ABSENT
	Black	Dk. br.	Light ¹	Brown ²	Blue		
15-19	2.3	41.1	1.6	3.0	13.2	44.2	89.2
55 +	2.4	56.5	1.9	5.2	12.0	47.8	88.4

¹ Includes golden, ash brown, and ash.

² Refers to dark, dark-light, and light brown.

Indeed, considerable morphological divergences occur between the Irish males and females. Although Professor Hooton's manifest loyalty to each of his co-authors makes him initially reluctant to consider the possibility that such differences could be the result of varying techniques, he later does acknowledge such a likelihood (p. 287). As remarked by Professor Hooton, the theoretical scale of reference in morphological observations as to size, at Harvard is supposed to be that of the modal Northwestern European male, and such judgments, even those for color and texture, are more or less subjective and liable to personal variation. Pertinent in this connection are the substantial differences in the proportion of males with light and dark eyes, and with black and light hair, as found by Dr. Dupertuis and by several other observers of the Irish (tables V-45, 47, 49, 50).

Another matter of obvious relevance is the justification for dividing a population into several morphological or "subracial types" by

means of a rigid sorting method such as that noted at the beginning of this review. Plainly, such a method might well place members of the same family in different subraces. The method, too, seems to question the fact of normal variability within any racial or subracial group. Yet, if the premise is correct that an original "pure" subrace within the white stock refers, for example, to a geographical group *all* of whom had fair hair and skin, blue eyes, a relatively long head, and were tall in stature (Nordic), or a population *all* of whom were medium or short in stature and had dark hair, dark eyes, and relatively long heads (Mediterranean) — then it seems to me the sorting of a population on the basis of the aforementioned criteria should be valid and differentiate "subracial" components (assuming the criteria are accepted as indicative of race). To be sure, how far back one must go to reach the "pure" groups, is not clear. Indeed, there may well be some question whether any such "pure" subraces ever existed. In any event, the sorting method is rigorously objective and descriptive albeit it appears to be based on this assumption of original "pure" groups in the sense noted above.

Many thought-provoking passages occur in the present work. Some of these have been noted. To mention only two or three others, Professor Hooton's observation of a "tendency of the women to preserve better the ancestral racial types, and of the males to vary away from these types in the direction of blended, composite, or hybrid types. . . ." (p. 284), would seem to merit further attention, especially since it is not uncommon for physical anthropologists to consider males only in racial analyses and classifications. A section devoted to Professor Coon's analysis of the Irish, mentioned previously, is also a pertinent critique of subjective methods in racial classification (pp. 239–243). Indeed, according to Professor Hooton (p. 121):

The whole method of attempting to describe races or groups by combinations of isolated arrays of means and measurements and modes of attributes is, in our opinion, obsolete, fallacious, and downright erroneous. It results in the setting up of hypothetical and entirely supposititious racial or group abstractions, so that a population is described in terms of a non-existent individual characterized by fictional average dimensions and combinations of modal morphological features which in reality may never occur together.

We had thought that physical anthropology was through with this hoary sinner — the fictitious average type — but unfortunately such is not the case. There has arisen a group of geneticists who are interested in physical anthropology, but know little about it, and another group of physical anthropologists who are interested in genetics without knowing much about that, who have revived the old idea of talking about "populations" as if they were races or subspecies. These workers concern themselves

with isolated variables and attributes because they are afraid to study individual combinations allegedly for fear that they will "mistake phenotypes for genotypes." Actually they are afraid to use the term "race" in any except the most generalized application, lest they be accused of "racial discrimination" or of being "racists." They are willing to have "races," but they are loathe to assign any individual to a race, because they think of "races" as being "populations" or "groups." This is absurd. If there is a Negro race, there must be Negroes. The same thinkers, if they can be so designated, are equally opposed to individual constitutional "types"—and for the same reasons.

Whether or not one agrees with all that Professor Hooton has written, there can be no denial that much of it is stimulating and provocative, and hence broadly useful, if read critically. In sum, the present massive work, in the reviewer's opinion, is a definitely valuable contribution. It provides a wealth of information about the Irish, and in many ways (some of them indicated in the preceding, it is hoped) should be of substantial interest to the general field of anthropology.

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FRANÇOIS JOSEPH GALL ET SA COLLECTION. By Erwin H. Ackerknecht and Henri V. Vallois. *Mémoires du Muséum National d'Histoire Naturelle*, n.s. Sér A, t. 10, fasc. 1, pp. 92, 2 pl. Paris, 1955.

PHRENOLOGY: FAD AND SCIENCE. A 19TH-CENTURY AMERICAN CRUSADE. By John D. Davies. 203 pp. Yale Univ. Press, New Haven (Yale Historical Pubs., Miscellany 62), 1955.

Phrenology was the 19th Century's practical psychology, offering answers to every problem from the selection of a wife or a railroad trainman to the rehabilitation of criminals and the education of the blind. In its heyday it attracted scientists and charlatans, physicians and preachers, writers and reformers. To the 20th Century it left a varied legacy, including octagon houses, educational theories, cranial

collections, fortune tellers, and, appropriately, Gall's skull and Spurzheim's brain.

The two publications reviewed here trace the phenomenal rise and fall of this quasi-science. Ackerknecht and Vallois describe the work of Gall, the anatomist, who died in 1828. Davies takes up the story with the arrival of Gall's associate and disciple Spurzheim in Boston in 1832, and traces the descent of phrenology to the Fowler family, who made the new science a paying proposition.

Ackerknecht and Vallois have done much to redeem Gall's reputation as a scientist by their summary of his very real contributions to anatomy and psychology. Gall was an excellent anatomist, widely respected by his contemporaries, most of whose work has stood the test of time. Had he been content to describe the structure of the brain and the nervous system all would have been well. Since, however, he was a firm believer in the interdependence of structure and function, it was only natural that he should believe that from the size of the structure one could predict the development of the function located there. He had also demonstrated by comparative anatomy that the brain was composed of individual systems which made their appearance in a definite phylogenetic and ontogenetic sequence. On these premises he proposed 4 basic psychophysiological theories: (1) Moral and intellectual faculties are inborn; (2) they have an anatomical basis; (3) they are located in the brain, and (4) the brain is therefore composed of the organs in which these faculties are located. These theories were received with mixed reactions by his contemporaries. The first, pregnant with dangerous philosophical implications, was denounced by political and religious leaders as materialistic and therefore dangerous to morals; the second smacked of the discredited physiognomy of Lavater; the third was in opposition to leading psychologists who placed the seat of the emotions in various places, including the thoracic and abdominal viscera, and the 4th, the localization of functions, was in contradiction to contemporary opinions that the brain functioned as a whole. The latter theory had the best basis, for Gall drew his evidence from comparative anatomy, pathology, and parallels between the mental evolution of the child and the physical evolution of its brain.

The extensive use Gall made of the evidence available is seen in the collections he assembled: Before he left Vienna in 1805, he had gathered over 300 skulls and 120 casts, most of which remained in Austria (Ackerknecht and Vallois note that Gall's three chief interests were science, gardening and women). In Paris he gathered more skulls: 174 skulls of quadrupeds, 138 birds, in addition to 354 "phrenological pieces." The latter consisted of 221 skulls, 102 casts of heads and 31 casts of brains; the subjects represented were 103

celebrities, 69 criminals, 67 insane, 35 pathological cases and 25 individuals of non-European races. Despite the many hands through which the Paris collection passed between Gall's death in 1828 and 1950, only 20 of the specimens were lost. An analysis of this collection and the description of a few of the more important pieces in it forms a prominent part of the study by Ackerknecht and Vallois. This study, supported in part by a Wenner-Gren Foundation grant was a practical necessity, for during World War II, the records pertaining to the specimens were lost when the German army confiscated Gall's collection, on the grounds of his birth in Germany. Anyone familiar with museum work knows the uselessness of collections without documentation, and the difficulties of reconstructing records once they are lost. A glance at the catalog shows that this collection was well worth the work involved.

The various reactions to Gall's psychophysiological theories are interesting: In Austria he was forbidden to teach, and his books were put on the Index by the Catholic Church. In France his views were considered somewhat extreme, but acceptable because their anatomical basis was demonstrable. In Germany they were rejected because they were not romantic enough. In Europe, the controversy seems to have been restricted pretty much to scientific circles; but in America the situation was exactly the opposite. Except for a few skeptics, phrenology was espoused fervently by scientists and the public alike, and its influence pervaded almost every phase of American life.

For all practical purposes, phrenology in America began with Spurzheim's visit here in 1832. Davies tells a fascinating tale, which begins with Spurzheim's death in Boston, his public autopsy (Dr. John C. Warren of Harvard dissected while James Audubon and other artists made sketches) and his funeral (attended by some 3000 citizens, including the Boston Medical Society in a body) while the city bells tolled for a public calamity. Spurzheim's short lecture tour had aroused considerable interest among the intellectuals, but the dramatic circumstances of his demise attracted even wider attention to his theories. There were many in Boston ready to satisfy public curiosity as to Spurzheim's views.

As interpreted by Spurzheim, phrenology was a hopeful doctrine, on supposedly firm scientific ground, which could be applied to almost any problem from the raising of children to religion. Although men were not *created* equal in abilities, by proper training they could *become* equal. Desirable mental and moral traits could be developed, and undesirable traits controlled, either by channeling them into acceptable directions or strengthening other traits to offset them. One

had only to observe, interpret and recommend suitable education. These ideas were simple enough to be understood by the layman, and the wierd assortment of busts, skulls, calipers, charts and other paraphernalia used by its practitioners virtually guaranteed an audience. In a short time travelling phrenologists were as common as patent medicine salesmen, and almost everyone in public life had had his cranial measurements taken to satisfy public curiosity. To meet the demands of an obviously expanding market, the Fowler brothers, Orson and Lorenzo, began publishing phrenological tracts and founded a school where proper training in the new science could be had. In the following years, their phrenological journal was enlarged to take in almost every reform conceivable, and their later associates included Sylvester Graham (Graham crackers), Amelia Bloomer (bloomers), Joel Shaw (the Water Cure), and others less prominent.

Though Davies' book is peopled by some colorful quacks, ample justification for Yale University to publish his study is found in the attempts of such figures as Horace Mann, Samuel G. Morton, Benjamin Silliman and Horace Greeley to apply the new science to practical problems. The account of the serious side of phrenology—in its relations to education, insanity, penology, health, literature, medicine and religion—forms the major part of the book. Unfortunately, from the standpoint of the reviewer, physical anthropology is barely mentioned, though there are ample references to cognate fields. It was in this respect alone that Davies' book was a little disappointing.

Both of the books—the account of Gall's work, and its subsequent transit to the New World—are excellent reading. Both have the merit peculiar to historical studies: By reconstructing the intellectual and social background of a period, men of the past and their ideas may be seen without the distortions introduced by later climates of opinion. Presented against the background of a sophisticated French science dominated by Cuvier and the other comparative anatomists, the reception accorded Gall's anatomical and psychological theories is understandable. Similarly, the adoption of Spurzheim's hopeful new philosophy of psychology and physiology is seen to be perfectly compatible with an optimistic new democracy. Although the material presented by Ackerknecht and Vallois is more directly relevant to the history of physical anthropology, there is much pertinent information to be found in Davies' account of Gall's influence on related fields. Not least is the extensive documentation of both books, which are invaluable reference sources for the periods they cover. For these reasons, both can be recommended to any physical anthropologist interested in the history of his science.

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MAN IN A COLD ENVIRONMENT. By A. C. Burton and O. G. Edholm, Edward Arnold Ltd., London, 1955.

MAN IN COLD ENVIRONMENT: A STUDY IN PHYSIOLOGY. By Loren D. Carlson, Alaskan Air Command, Arctic Aeromedical Laboratory, Ladd Air Force Base, Fairbanks, Alaska. August, 1955.

Students of human evolution have recently stubbed their collective toes on what promises to be the greatest advance in the field since genetics. Following the discovery that a study of blood chemistry aided in sorting *Homo sapiens* into genetic groups, choice bits of information have filtered into the field from physiology, biophysics, experimental psychology, pathology, biochemistry, and almost every other scientific discipline that is concerned with man. The anthropologist who tries to utilize and evaluate this multitude of data quickly realizes his inadequacies. As Coon so succinctly stated the case, "Just this small amount of contemplation has made it abundantly clear to me that if a person is to study the racial variations in man in terms of ecology, he must be a superscientist, thoroughly conversant with not only his own subject, including anatomy, but also physiology (particularly heat-and-sweat physiology), nutrition and growth, radiation physics, optics, body mechanics, genetics, and cultural anthropology in time and space." As there are few superscientists among us, the obvious alternative is to seek our information from the experts in the respective disciplines. Even this solution is not totally satisfactory. The physiologist, for example, does not formulate his problems or organize his data within evolutionary concepts. Even his terminology reflects a different orientation. A discussion of adaptation in man by a physiologist and an anthropologist leaves both in doubt concerning the other's scientific ability, primarily because of the difference in orientation. To the physiologist, adaptation may signify a rapid short-term process such as dark adaptation or adaptation of receptors. Obviously, this usage is not encompassed by the anthropologist's concept of adaptation. For the full exploitation of the data in other scientific fields the anthropologist must obtain at least a rudimentary knowledge of the discipline he wishes to utilize.

To learn something of the physiology of man in the cold there is probably no better source than Burton and Edholm's new book *Man in a Cold Environment*. This book has been written in the clearest and most readable style possible for such a technical subject. The novice in physiology will probably find some of the mathematical formulations beyond his interest, but he can still derive an understanding of the basic mechanisms by which man, as a tropical homeotherm, has adapted himself to colder climates.

Doctors Burton and Edholm have devoted considerable thought and space to a discussion of the whys and hows of homeothermy. They have also devoted a considerable amount of space to a comparison of the adaptive mechanisms of non-human animals versus *Homo sapiens*. Despite their attempt to bring a closer correspondence between the concepts of physiology and evolution, certain unbridged gaps are apparent. The physiologist observes gross differences in the mechanisms by which various genera of animals maintain their homeothermic existence. In extreme cold the poikilotherm can hibernate and his body temperature will fall without damage below levels which would be lethal to other mammals. Birds would be quickly driven out of cold areas if it were not for the autonomic regulation of the blood flow to the extremities. Many arctic mammals depend primarily on adjustable insulation, while most tropical animals rely on the increase of metabolically produced heat for cold protection. Most animals show a combination of these mechanisms and man with his usual catholicity has all of these built-in protections plus cultural aids. Within the broad range of thermal regulatory mechanisms, the racial and individual differences found with *Homo sapiens* is small indeed. This limited range has prompted at least one physiologist to conclude that there is no variation in adaptation within man (Scholander, '55). Such a conclusion is understandable in light of the range of mechanisms found in mammals, but it fails to take account of the small survival advantage required for a characteristic to become genetically established in a population. Burton and Edholm have not fallen into this trap and contrary to widespread usage in physiology, they are not willing to ascribe the difference in cold tolerance between Eskimos and Whites purely to environmental factors such as nutrition and acclimatization.

The authors of this book are a biophysicist and a physiologist and the book has very adequately surveyed current knowledge in these fields. However, it is regrettable that neither author had a knowledge of physical anthropology. The book would have been much more satisfying if it had incorporated the data on bodily characteristics in relation to cold that have been discussed by Coon, Roberts, Schreider, Newman and others. I still highly recommend *Man in a Cold Environment* to all anthropologists who are interested in the biological and cultural adaptiveness of man.

Doctor Carlson's book *Man in Cold Environment* unfortunately has an almost identical title to the one by Burton and Edholm. As the two books were published almost simultaneously, the confusion is understandable. Carlson's book is definitely not recommended for beginners, despite his statement to the contrary. The monograph is

highly condensed and by the author's admission has many gaps. The novice will find himself involved in complex formulae on the first page and, if not a reviewer, will probably give up before page 10.

This is not to say that Doctor Carlson's book is without merit. For the individual who is familiar with basic physiology this monograph has two qualities that make it useful. First, it presents and carefully explains a majority of the formulae used for calculating man's thermal interchange in the cold, and second, it has the most complete bibliography available on man in the cold. These two attributes make Carlson's book a worthwhile contribution, but for the general reader, I definitely suggest Burton and Edholm's fine book.

LITERATURE CITED

- COON, C. S. 1953 *Climate and Race in Climatic Change*, edited by Harlow Shapley. Harvard University Press. Cambridge. 1953.
- SCHOLANDER, P. F. 1955 *Evolution of Climatic Adaptation in Homeotherms*. *Evolution*, Vol. 9, No. 1, p. 15.

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BOOK NOTES

PHYSICAL GROWTH OF CALIFORNIA BOYS AND GIRLS FROM BIRTH TO EIGHTEEN YEARS. By Read D. Tuddenham and Margaret M. Snyder. iv + 364 pp., Illus. University of California Press, Berkeley and Los Angeles, 1954. \$2.00.

This latest University of California Publication in Child Development consists of 29 pages of textual and explanatory material, and 135 pages of raw anthropometric data presented child by child, and covering the period birth to 18 or 19 years. The analysis includes age trends for height, weight, stem length, the bi-iliac and biacromial diameters, leg circumference and strength: these are erroneously labeled as showing "annual growth." The most interesting part of the analysis consists of the interage and intermeasurement correlations for the 60-70 boys and girls: here the correlation of 0.60 between height at two years and height at 18 years comes as some surprise but this value of r is surpassed by stem length, and several other measurements. "The most predictable dimensions seem to be those which involve primarily skeletal size" write the authors (p. 216).

The raw measurements, which by the way, are generally "smoothed values corresponding to actual observations made within ± 0.2 years of the age level indicated" (p. 228), may be of considerable use to other workers interested in growth, but lacking access to longitudinal data. Again the raw data can be used for class exercises in statistics, trend analysis and graphic representation: the inclusion of somatotype estimates, and the age of skeletal maturity enhance their use for such purposes. However, one cannot refrain from expressing the regret that so much work, and so much care expended over a 20 year period, has not yet contributed more to our knowledge of human growth. Further analysis of the data is much to be desired.

STANLEY M. GARN

THE DIRECTION OF HUMAN DEVELOPMENT. BIOLOGICAL AND SOCIAL BASES. By M. F. Ashley Montagu, pp. 404. Harper & Bros., New York. 1955.

The purpose of this book, as stated by the author, is to answer the question as to what is man's original nature and how is this nature

influenced and conditioned to assume a socially functional form. A sub-title of the book states that it is "A scientific confirmation of the enduring belief that human love is essential to all social growth." Biological, social, psychological and anthropological fact and opinion is mustered by Doctor Montagu to support the thesis that love and cooperation are the foundation stones of human society.

F.P.T.

The following 5 items received from the Polskie Towarzystwo Antropologiczne, Wroclaw, Poland, Ul. Kuznicza Nr. 35:

ANTHROPOLOGICAL REVIEW. Vol. XXI, Part 1. 1955. Reports of conferences, original papers, review articles, and summaries of Polish research activities are given. Mostly in Polish but with some articles and summaries in English.

MATERIALS AND ANTHROPOLOGICAL MONOGRAPHS:

No. 3 *Crania et alia ossa Polonica, Early Mediaeval Cemetery in Koneskie*. By Jerzy Damski, pp. 54. 1955.

Reports measurements from 153 skeletons, giving detailed data and an analytic summary.

No. 4 *Fragmenta Craniologica, The Cemeteries from Poland and Neighboring Countries*, pp. 154. 1954.

Measurements of some 165 Neolithic, Medieval, and 17th Century specimens from 8 sites are given in detail.

No. 8 *The Anthropological Structure of the Polynesians*. By Aleksander Lech Godlewski, pp. 63. 1955.

A study of Polynesian affinities and migrations based upon various typological analysis methods and using published data.

No. 9 *The Morphology of the Auricular of the Inhabitants of Hlucin*. By Milan Dokladal, pp. 65. 1955.

The ear morphology, in whole and parts, is described in considerable detail on 326 subjects (184 males and 142 females) from the district near the Czechoslovak-Polish frontier. Group frequencies by sex are given for the many traits examined, but are not grouped by families.

F.P.T.

ARM STRENGTH AT SELECTED DEGREES OF ELBOW FLEXION. By Paul A. Hunsicker, pp. 58. WADC Technical Report 54-548. Wright Air Development Center, Ohio. 1955.

The report abstract states, "A selected summary of the strength testing literature forms the first part of this study. This is followed by a listing of the modifications that had to be made on the Kinematic Muscle Study machine as a result of exploratory testing. The major portion of the investigation is concerned with the results of testing 55 young men on 60 arm strength tests in the sitting position and 60 in the prone position. Percentile tables and figures depicting arm strength in relation to degrees of elbow flexion are included. Recommendations for further use of the Kinematic Muscle Study machine are offered."

F.P.T.

ANALES DEL INSTITUTO NACIONAL DE ANTHROPOLOGIA E HISTORIA. Tomo VII, No. 36. Secretaria de Educacion Publica, Mexico. 1955.

Original articles on prehistory, archeology, and human biology which deal particularly with Mexico are included in this volume. Of particular interest is the article, with measurements and photographs, by Romano on the human remains found at Santa Maria Astahuacan by George O'Neill in 1953.

F.P.T.

ANTHROPOLOGICAL AND OPHTHALMOLOGICAL STUDIES ON THE ANGMAGSSALIK ESKIMOS. By Erik Skeller, pp. 231, 7 plates, 21 figs., 86 tables. Meddelelser om Grønland, Bd. 107, No. 4. Translated from the Danish by Mrs. S. Hellmann. Bianco Lunos Bogtrykkeri A/S, København. 1954.

This excellently prepared monograph deals with the Angmagssalik Eskimo in light of his history, the anthropometry of related groups, and the anthropometry and ophthalmology of this particular group. Extensive measurements, set in a comparative framework, and many detailed observations on eye form and function complete this study. Eye refractions, all too rare in anthropological investigations, are reported. The results of 355 blood typings for ABO, MNS, P and Rh, to mention only one part of this highly informative report, are given in detail.

F.P.T.

HANDBOOK OF VITAL STATISTICS METHODS. Series F, No. 7, Studies in Methods. \$2.50. United Nations, New York. 1955.

The purpose of this publication is to assist countries in the development and appraisal of vital-statistics service. While it recommends many measures to insure the standardization of practices in the countries of the world, it is of interest to anthropologists more for its summary of current procedures in all the nations which record such data.

F.P.T.

CRESCENT AND GREEN. A miscellany of writings on Pakistan, pp. 170. Philosophical Library, New York. 1956.

Sixteen short articles on the culture-history of Pakistan, by such authors as A. J. Toynbee, V. G. Childe, Mortimer Wheeler, are included in the book. The articles by Childe is of special interest because of its evaluation of the place of the early Indus valley cultures in the development of Western civilization.

F.P.T.

LE CIMETIERE DU XI^e SIECLE DE KERPUSZTA. By P. Lip-tak, J. Nemeskeri and B. Szoke, pp. 370, Illus. Acta Archaeologica Academiae Scientiarum Hungaricae. 1954.

This monograph (in French) includes descriptive data and measurements of each specimen plus an analysis of associated archeological material and the racial relationship of this population. Descriptive data of the skeletal and associated finds in 388 graves makes this a valuable collection of detailed data from a single population.

F.P.T.

HEALTH, CULTURE, AND COMMUNITY. Case Studies of Public Reactions to Health Programs. Benjamin D. Paul, Editor, with collaboration of Walter B. Miller, pp. 493. Russell Sage Foundation, New York. 1955.

Sixteen different authors' works are collected here in the attempt to put problems of public health in a cross-cultural perspective. The success or failure of specific public health programs is related to the

socio-cultural system in which they were attempted. This points to another cross disciplinary link between the biological and social sciences which should be of increasing practical importance.

F.P.T.

RACES AND PEOPLE. By William C. Boyd and Isaac Asimov, pp. 189. \$2.75. Abelard-Schuman, New York. 1955.

A simple explanation of genetics and an explanation of race in these terms is accomplished in this book. It is intended for high school students and should have a great value by setting an authoritative foundation for studies of the race problem at a school level where they can be most effective.

F.P.T.

RADIOCARBON DATING. By Willard F. Libby, with a chapter by Frederick Johnson. 2nd Edition, pp. 175, \$4.50. University of Chicago Press. 1955.

Improvements in measurement techniques developed since the first edition and hundreds of additional dates as determined in the University of Chicago laboratory are reported. Frederick Johnson has added an important chapter of the significance of radiocarbon dates in the reinterpretation of pre-history.

F.P.T.

FACE OF THE DEEP. By Dudley Joseph Whitney, pp. 102. Vantage Press, New York. 1955.

For the collector of curious explanations of earth history and defenses of the story of Divine Creation, this book should be of interest as it places the beginnings at some 6000 years ago. It is written in light of rather unusual interpretations of what is ordinarily taken as evidence of a great antiquity for our earth.

F.P.T.

THE VERTEBRATE BODY. A Shorter Version of the 2nd Edition. By A. S. Romer, pp. 486, Illus. W. B. Saunders, Philadelphia. 1956.

The second edition of this highly successful text has been reduced from 644 pages to 486 in the interest of fitting it more comfortably

into the space afforded by some college course schedules. The beginnings and end of the full edition are retained, including the appendices and index, but the middle chapters are reduced appreciably. It must certainly be up to the individual instructor to decide which form best fits his purposes, but having a choice must be of value to many.

F.P.T.

SOCIAL MEDICINE. By S. Leff, pp. 297. Routledge & Kegan Paul, London. 1953.

S. A. Barnett, as editor of the *Survey of Human Biology* series planned by these publishers, has chosen this first volume well. This series, which is planned to cover the main fields of human biology, is addressed to the specialist who is in disciplines related to human biology and who is interested in the biology of man as a species. This volume fits well into the plan. It discusses the problems of applying scientific medicine to the peoples of the world and the changes in populations that are a consequence of such application. Well documented, this book shows how far the problems of man as a social animal are ahead of the efforts of orthodox medical practice in solving them.

F.P.T.

REPRODUCTION AND SEX. By G. I. M. Swyer, pp. 280. Routledge & Kegan Paul, London. 1953.

This is volume 2 in the *Survey of Human Biology* series. This book sets out to provide a clear and comprehensive account of the human reproductive system and fully accomplishes this purpose. It is a fine addition to this series and adds to the pace set by the first volume.

F.P.T.

RAZZE E POPOLI DELLA TERRA. By Renato Biasutti. Vol. III, Africa, pp. 720, Illus., 2nd Edition. Unione Tipografico-Editrice Torinese, Torino. 1955.

Heavily illustrated in black and white and with many color plates, this is the third volume in the reprinting of the series by Biasutti and his collaborators. It deals with the prehistory, races and culture of

Africa in a traditional anthropological framework but at an encyclopedic level. The previous two volumes, *Razze, Popoli e Culture* and *Europe-Asia*, and the present volume will be followed by *Oceania-America* which will complete the series.

F.P.T.

BASIC STATISTICAL CONCEPTS. By J. K. Adams, pp. 304. \$5.50. McGraw-Hill, New York. 1955.

For the instructor who seeks a book on statistical methods and concepts which can be used to introduce the college student of average mathematical training to the tools of statistics, this text should be of value. While it is not oriented toward biological problems, it does cover the methods which may be of use in biological studies.

F.P.T.

Psychiatric Research Reports of the American Psychiatric Association. 1785 Massachusetts Ave. N.W., Washington 6, D. C.

No. 1 *Pharmacologic Products Recently Introduced in the Treatment of Psychiatric Disorders*, pp. 152. \$2. July, 1955.

No. 2 *Approaches to the Study of Human Personality*, pp. 176. \$2. December, 1955.

These two reports introduce a new series of research reports.

The International Journal of Social Psychiatry. 9 Fellows Road, London N.W. 3, England. Vol. 1, No. 1. Summer, 1955. Quarterly. Annual rate \$5.

Introducing a new journal.

MAN'S ANCESTRY. By W. C. Osman Hill, pp. ix + 194, Illus. 21s. Od. William Heinemann Medical Books Ltd., London. 1954.

This is a clear, concise and critical account of human phylogeny. It is based on an excellent series of lectures delivered at Edinburgh University to those undergraduates desirous of acquiring a "working knowledge" of physical anthropology. However, although the preface also claims that the book is "intended for the intelligent layman," the reviewer doubts the ease with which the layman will fully grasp, even with the aid of the appended glossary, the first few chapters on the evidence for evolution and the evolutionary horizons in human

phylogeny. Nevertheless it places the whole story of evolution in a nutshell.

Some outstanding features are the clarity of the photographic plates, the quality of the diagrams(drawn mainly by the author's wife) and the bibliography — a well chosen guide for those interested in detail.

The first two-thirds of the book deals with the evolutionary stages leading up to the emergence of Man; whereafter, the more important types of fossil and modern man are well-described and discussed. These latter chapters contain sections which should be most thought-provoking to an under-graduate as well as to the professional anthropologist.

It is also regretted that the author does not even mention the possibilities of tracing the blood-group genes in Man's history. As a matter of fact, he seems to neglect genetics completely despite its rapidly increasing importance as a weapon in the physical anthropologist's armamentorium. Despite these minor frailties, this pocket-size edition of Man's ancestry is highly recommended to teaching anatomists and anthropologists.

RONALD SINGER

PROCEEDINGS
of the
TWENTY-FIFTH ANNUAL MEETING
OF
THE AMERICAN ASSOCIATION
OF PHYSICAL ANTHROPOLOGISTS

The twenty-fifth annual meeting of the Association was held in Chicago, Illinois, on Friday, Saturday, and Sunday, April 6, 7, and 8 at the invitation of the Department of Anthropology of the University of Chicago. All events of the twenty-fifth meeting took place in the main ballroom of the Shoreland Hotel, on 5454 South Shore Drive, Chicago 15. These events included a symposial clarification of the ecological, evolutionary, and taxonomic position of the South African Australopithecines (led by Washburn on Saturday afternoon), a panel discussion on "identification" (led by R. Newman on Sunday), and highlights at both dinner (president Trotter on anniversary history) and business meeting (race attitudes). This program attracted 79 members and 83 guests, a record registered attendance of 162.

After the general sessions on Friday, the Wenner-Gren Foundation for Anthropological Research generously sponsored a Supper Conference for discussion of publication problems. The Editor of the American Journal of Physical Anthropology, Dr. S. L. Washburn, pointed out that by decentralizing, the Journal has been able to accept more papers, so that 600-700 pages per year are needed in future, rather than the 500 pages which the sponsoring publisher, The Wistar Institute, can manage with present increased costs. We are most grateful for past help in providing extra pages both to The Wistar Institute and to the Wenner-Gren Foundation. We list

them as Benefactors of our Association. We would welcome other benefactors. Now how do we raise an extra \$1,500 or more per year? Increased membership and subscriptions help, and an item from each author for cost of publication of tables and plates would help even more. Further, since this is no longer a journal for Lehrbuch physical anthropology and since human evolution is both the central theme of our subject matter and a salable title, why not change the name of the Journal to "Human Evolution and Variation?" We would then stress articles of service to biology and social science teachers. This idea provoked discussion in which a plurality favored retaining physical anthropology in the Journal's title in order to show our place as part of anthropology rather than as an outlier of biology. But the evocative quality of the term "evolution" and the need for our leadership in guiding high school study of primate evolution brought the compromise suggestion of a second journal, more popular and perhaps like the successful "Archaeology" of the A.I.A. Thus we decided on no new source for funds. The business meeting and the Smoker immediately followed this discussion.

The annual dinner, held on Saturday evening, was a celebration of the 25th anniversary of the Association's existence led by the president and attended by 77 people including four of the 84 charter members of the Association (Herskovits, Papez, Stewart, Trotter). The presidential address follows:

Notes on the History of the AAPA

MILDRED TROTTER, *President*

The University of Chicago was host to us in 1941 at our twelfth meeting. That year was the fiftieth anniversary of the founding of The University of Chicago. It was very adventurous in those days for a meeting to be held so far away from "the East" and the choice was undertaken with some trepidation. Justification was made on the basis that although the majority of members live in the East, this might be counterbalanced by the desirability of arousing interest farther west (AJPA, 27: Sup., 5, 1940). We survived that long trek so well, had such a good time and thrived after the experience that we came back to Chicago in December 1946 for a meeting in conjunction with The

American Anthropological Association. We accepted Doctor Washburn's invitation for this meeting with alacrity. We are glad, indeed, to be here again for our twenty-fifth meeting; Chicago has a warm place in our hearts.

Because it is our twenty-fifth meeting it is appropriate to look into the past and to review some of the experiences which have made us what we are today.

We didn't just grow up like Topsy. For many years we were only a well concealed gleam in Doctor Hrdlička's eye. That he had held the thought of our conception for a long time before the event becomes evident as we review the records of the efforts that went into the founding and development of our journal. It is unlikely that the Association would have been organized at the time it was, had it not been for the well-established journal—so, in order to understand our early history better it is necessary to review briefly some of the circumstances related to the founding and early years of the journal.

Doctor Hrdlička first started to advocate the establishment of a journal of physical anthropology in 1908; in 1916 he presented the proposal in definite form to the subcommittee on Anthropology of the Committee of One Hundred on Research of the American Association for the Advancement of Science. It received the full support of both the subcommittee and the committee. Late in 1917, approval was seconded by the secretary of the Smithsonian Institution, by the Committee on Anthropology of the NRC, and by the American Anthropological Association. One argument for its promotion had been that "The U. S. is the only one of the larger civilized countries that, as yet, has no periodical devoted to this branch of science. Even Portugal and Switzerland now have such journals" (AJPA, 1: 1, 1918). The first issue, Jan.-March, for it was a quarterly from the beginning—and late in arriving, I might add—was received in our library at Washington University on July 12, 1918. Doctor Hrdlička's name appears on the front cover as founder and editor along with the names of 17 associate editors. The annual subscription price was \$5.00 (now it is \$7.50). The Journal was printed for the first three years by The Press of the New Era Printing Co., Lancaster, Pa., and was sent to Washington, D. C., to be mailed. The fourth volume was printed by The Shaw Printing Co., Battle Creek, Michigan and was mailed from Washington. The next three volumes (5, 6 and 7) were not only printed, but also mailed, by the Geo. Banta Publishing Co., Menasha, Wisconsin. The eighth and ninth volumes were printed and mailed at Geneva, New York by W. F. Humphrey. During this entire period, subscriptions were sent to the editor, and during much of this time the editor had, not only to give all printing directions, but also, to arrange for

half-tone and line engravings. Think of his patience, perseverance and endurance!

There is evidence in the Journal under rules concerning communications that it was not self-supporting: "Until the Journal is on a sound financial basis, illustrations, detailed tabular matter, extended quotations in foreign languages, and extensive use of mathematical formulae, must be restricted, unless their expense is borne by the author or his institution" (AJPA, 1: 1918). Reports during this period (and since) indicate that Doctor Hrdlička solicited donations in aid of the Journal. It is of interest that sizable contributions came from Mrs. Earnest Hooton, Geo. M. Kober, Geo. E. Hale, Irving Fisher and J. H. Kellogg. (Mrs. Hooton's donation was the largest.) Many times Doctor Hrdlička met the shortages out of his own pocket.

With the tenth volume Doctor Hrdlička must have felt great pride, for The Wistar Institute Press had become the publisher. Subscriptions were sent directly to Philadelphia. The details of business arrangements were now shifted, but not the responsibility of finding sufficient money (chiefly through new subscriptions) to meet the cost to The Wistar Institute. (The problem of financing the journal has continued, as we all know.) The fact that The Wistar Institute was willing to undertake the publication of the Journal spoke for its need in the scientific world and its high standard and, thus, must have given great encouragement to the editor and to the editorial board. It should not be forgotten that "when this Journal was turned over to The Wistar Institute in 1927 his (Doctor Hrdlička's) substantial endowment went with it" (AJPA, 26: 19, 1940). He continued as editor through 1942 and by this time the number of associate editors had been reduced to eleven. It was during this year that he expressed his desire to Doctor Farris to retire as editor. He was 73 years of age. At the request of Doctor Farris, Doctor Hrdlička suggested Doctor Stewart as editor and 4 others, as associate editors. Doctor Farris reported:

"These suggestions met with the approval of the Institute, and Dr. T. Dale Stewart has been designated as Editor for a period of 6 years, commencing with the new volume to appear in 1943.

"The Associate Editors are satisfactory to Doctor Stewart, and unless the Association has some real objection, it is the desire of the Institute to appoint these members as Associate Editors. Since they have not yet been approached by the Institute regarding appointment, it will be appreciated if the Association asks them to serve, designating the length of term each is to serve, one expiring in '43, one in '44, one in '45 and one in '46. Thereafter, as terms expire, it is our wish that the Association nominate and elect successors for a term of four years.

"It is hoped that all of the foregoing appointments meet with the unanimous approval of the Association, and further, that the Association will extend to The Wistar Institute greater future support in the conduct of The American Journal of Physical Anthropology, so that the Institute may pass to the Association the right to nominate the Editor when the term now served by Doctor Stewart expires, it being understood, of course, that election of the Editor rests with the Board of Managers of The Wistar Institute" (AJPA, 29: 313, 1942).

Doctor Stewart wrote in the first issue under his editorship: "The new Editor is aware of a triple responsibility: To Doctor Hrdlička, who established the Journal; to the Association, of which it is the organ; and to The Wistar Institute, its publisher" (AJPA, n.s. 1: 2, 1943). I should like to suggest that the Association also has a triple responsibility: to the memory of Doctor Hrdlička, our founder; to the editor, whom we propose to The Wistar Institute; and to The Wistar Institute, which contributes so much to the dissemination of our science.

The need of an organization of physical anthropologists was beginning to be felt in the early twenties. An increasing number of biologists were submitting manuscripts for publication in the journal. In 1924, Doctor Hrdlička proposed the organization, but too many workers in the field, led by T. Wingate Todd, felt that the time was not quite ripe. At the ninety-fifth meeting of the AAAS, held in New York, in December 1928, the first steps were taken by the well-attended Section H. "A stimulating paper by Aleš Hrdlička led to the appointment of a committee to consider the best means for furthering the ends of American physical anthropology" (Sci., n.s. 69: 123, 1929). The time was opportune, for Doctor Terry was chairman of section H, Doctor Danforth was secretary, and Doctor Todd did not attend this meeting. "As a result, there met about twenty anthropologists and anatomists, and each of these individually and unreservedly expressed himself in favor of the founding of a special association for physical anthropology." The committee of organization with power to act was elected: Drs. Fay-Cooper Cole, Charles H. Danforth, George A. Dorsey, William K. Gregory, Earnest A. Hooton, Aleš Hrdlička, and Robert J. Terry. The committee elected Doctor Hrdlička, chairman, and Dr. Dudley Morton, secretary-treasurer. [In his report of these events in *Science* (n.s. 69: 304-305, 1929) Doctor Hrdlička signed himself, Chairman, p.t., AAPA.]

Correspondence between Hrdlička and Morton in 1929 reveals that, in April, Morton wrote to Hrdlička about membership for the new organization and about the place and time of the first meeting. Hrdlička went off on an expedition to Alaska but Morton kept on the

job. He submitted to Hooton a list of 58 names as prospective charter members. Hooton suggested 5 additional names—all had been his students. Late in the fall Morton offered to act as host for the first meeting, if it could be held in New York. At about the same time, Danforth was arranging for the meeting to be held with Section H, which was scheduled for December at Des Moines, Iowa. The preliminary announcement in *Science* (n.s. 70: 528, 1929) of the Des Moines Meeting of the AAAS stated: "The meetings of Section H will be on December 30 and 31. One or more sessions will be held in conjunction with the newly organized American Association of Physical Anthropologists, and a very interesting program in this field is anticipated." A suggestion was made, also, to meet with the American Association of Anatomists at Poughkeepsie, but Hrdlička had returned to Washington and was holding out for a more auspicious occasion. When he learned that the anatomists were meeting in the spring of 1930 at The University of Virginia, he felt that this was what he was looking for. Doctor Bean, the professor of anatomy at the University of Virginia, was receptive to Doctor Morton's proposal and invitations to prospective charter members were finally sent out on December 30. As names continued to be suggested, invitations were sent right up to the time of the meeting.

In addition to sending Todd the standard invitation, Morton followed it up with a personal letter. On January 13, 1930 Todd wrote to Morton again: "In reply to your various communications regarding the American Association of Physical Anthropologists, I have thought over the matter very carefully and, as I told you in my last letter, the situation is materially different when faced with the actual existence of an organization. I agree with you that it is better for me to be within than without."

In retrospect, this resistance of Todd to the organization seems strange, particularly since so many of his papers had been published in the journal.

Finally, the nature of the joint session to be held in Charlottesville was suggested by Doctor Weed, the secretary of the anatomists; namely, that 6 or 7 prominent anatomist-anthropologists give papers of their choosing.

Enclosed with each invitation to join was a statement listing 12 objects of the new organization; the last one being "To the eventual establishment, in the most favorable location, of the 'American Institute of Physical Anthropology' . . ." Soon thereafter the announcement of the first meeting was made, and invitations for papers were given.

The meeting was held on April 17, 18, and 19, 1930 at the University of Virginia and provided 4 one-half day sessions (29 papers in all)

including one session which was held jointly with the American Association of Anatomists. The papers of the first meeting covered almost as wide a range of subject matter as the papers of the present meeting: evolution, race, "Form types of the body" (given by Doctor Hrdlička, no less), one paper on blood groups of Cree Indians, several on growth; one on the subject of "The adolescent lag," another on the "The adolescent spurt," others on teeth, brain, methods; and, another on "Changes in stature and weight of the female students at the University of Minnesota during the past eighteen years." Throughout the entire period including the present meeting, papers bearing on the subject of human evolution have been the most frequent.

The business meeting, open to all members, was held at the beginning of the first regular session. Reports of progress made by the organizing committee were presented. The chairman then appointed a Committee on By-Laws (Gregory, Bean, Schultz, and Morton) and on Nominations (Terry, Gregory, Danforth, Scammon, and Ernst Huber) with instructions to present their reports at the final session. At this first meeting were established two classes of membership, active and associate. A member of either category could become a life member on payment of \$25.00. The life membership privilege was not available after 1945 and those in this category were asked to pay annual dues. The possibility of becoming a benefactor on the payment of \$500.00 was established, also, at the first meeting. Ever since the 1948 meeting two benefactors have been listed in our Proceedings. They are the Viking Fund, Inc. (changed to Wenner-Gren Foundation for Anthropological Research, Inc.) and The Wistar Institute of Anatomy and Biology. The Viking Fund should have been listed almost from the time of its inception, 16 years ago, and The Wistar Institute from the time of our inception. Both have contributed immeasurably to our nurture.

At the last session of this first meeting the Constitution and By-Laws, with the inclusion of Objects of the Association, were adopted. The first objective, and perhaps, the most significant was — "To the promotion of contacts, of cooperation, and of service in this and other countries, with all branches of anthropology; with anatomists and physiologists; with the biologists; and with medicine and dentistry." (AJPA, 14: 324, 1930.) In the discussion it was emphasized, sufficiently to be recorded in the minutes, that "While our close affiliations with related societies should be borne in mind and encouraged, the society should maintain an independent position . . ."

Election of officers followed the recommendation of the nominating committee with Doctor Hrdlička for president (2 year term), Dr.

Dudley Morton for secretary-treasurer (5 year term) and Drs. Gregory, Hooton, and Terry for the executive committee (one to be elected annually). Another significant item of business was agreed to unanimously, that the AJPA be designated as the official organ of the society.

The Proceedings of the meeting (AJPA, 14: 321-329, 1930) include the list of charter members—84 in all, of whom two were women. Today, 27 years later, 48% of the charter members are dead, and only a few of the remaining 52% are active. Of the 44 remaining charter members, including those who are present, we have had responses from 26. Several have written of their recollections of the first meeting, or of incidents pertaining to it. Much of the flavor would be lost if you did not hear their very words so I shall read excerpts from their letters.

From Dr. C. H. Danforth (Professor Emeritus of Anatomy, Stanford University):

"I remember feeling somewhat perturbed at first, in that I found myself Secretary of Section H and a member of a group that might be regarded as seceding from it. This matter was discussed at the meeting of December 29 and was finally rationalized to everybody's satisfaction on the ground that it is a function of sections of the AAAS to foster and promote nascent groups until they are able to start out on an independent basis.

"What I remember about the Virginia Meeting—absurdly enough—is chiefly long brick walls and T. Jefferson's strategic position at Monticello!

"What I observe today is that the Association has taken a prominent place in the scientific world and outgrown the fondest hopes of its founders."

From Dr. W. K. Gregory (American Museum of Natural History):

"Although I was not present at the first meeting of the Association I was present at the meeting of Section H in New York in 1928 and discussed with the dynamic Doctor Hrdlička, or rather said yes to his effort to found the AAPA . . . the details were worked out by representatives of all concerned. Doctor Hrdlička's journal was taken as the base for the Association's journal and it was practically the nucleus for the then new society."

From Dr. J. C. B. Grant (Professor of Anatomy, University of Toronto):

"What I remember most clearly are the numerous and distinguished, and even legendary, personalities who attended the first meeting rather than the substance of their discourses. To take but two or three instances:

“There was Charles Davenport, who in his initials, in his interests, and his outward appearance, bore resemblance to the immortal author of ‘The Origin of Species’ whose portrait in profile is known to all. This he bore, not unwittingly, I think, and not unwillingly, I imagine.

“There was Robert Bennett Bean, the engaging host who genially welcomed the society to The University of Virginia. He recalled to my mind the fictional character in one of John Buchan’s novels, ‘The Man with the Eyes that Blinked.’ He must surely have been his prototype for, neither in the market-place nor in the crowd, however dense, could he have succeeded in concealing his identity — even had he wished to do so — for this fascinating trait of his would have penetrated any disguise.

“And there was Graves, who would not and could not be persuaded by the Chairman to sit down at the conclusion of his allotted time.

“Aleš Hrdlička was there, and there I first saw and met him and learned how his name should be pronounced.

“Surely, it was at this meeting that Hrdlička, after demonstrating several femora, each possessing a small and unusual tubercle, called the attention of the meeting to the fact that there was ‘still much to be learned from the study of bones.’ After showing some lantern slides, he said: ‘Make light,’ — but the room remained in semi-darkness. So, he turned round, and after he had fumbled on the wall for a few moments, — lo, there was light!

“This miracle, unrehearsed and relatively minor though it may have appeared in this instance, seemed to me to be of good omen for the future of the society that was then in its genesis. And, so it has proved to be.”

From Dr. T. D. Stewart (U. S. National Museum):

“My paper came the last day and was the first I had ever given before a scientific society. It seemed to go off pretty well and on the train coming back Hrdlička and others complimented me on it. However, Hrdlička took me to task for reading the paper. As a result, I have made an effort ever since to give my papers extemporaneously. Incidentally, sometime before I gave the paper (which was on the subject of dental caries), I encountered Harry L. Shapiro and he remarked, superiorly, I thought, ‘What is there new about dental caries that you can tell us?’ or words to that effect.

“I had too little background on the meeting and was altogether too naive to appreciate all that went on. I do recall that Davenport gave Hrdlička a lecture on statistics and especially the statistical concept of variation. Also, I was painfully aware at the dinner of Stockard’s oversight of Hrdlička.”

From Dr. Harold Cummins (Professor of Anatomy, Tulane University):

"A little reminiscence may be of interest to those who knew Hrdlička, and maybe to others, because his aversion to statistics must have become familiar by hearsay to those who came along too late to have that privilege. Among the papers presented was one by Edith Boyd. [As a matter of fact, this occurred at the third meeting but is of interest, nevertheless.] She and several collaborators had made repeated anthropometric determinations on the same series of subjects with the aim of analyzing quantitatively the error introduced by a single observer and the comparative errors of different observers. Her results were arrayed in tables, each item accompanied by the appropriate statistical constants. In those days 'probable error' was used more widely than 'standard error,' and she mentioned repeatedly the 'probable errors' of the means. I noticed that Hrdlička was twitching and uneasy during her talk, and at her last word he exclaimed: 'That illustrates exactly what I have been thinking and saying about the uselessness of statistics. Even Doctor Boyd admits that there are probable errors in her work.'

"As the program shows (*Am. J. Phys. Anthropol.*, 14: 83-90, 1930), several anthropological papers were presented in a joint session of the anatomists and physical anthropologists. Certain members of the latter group, Hrdlička included, felt that these contributions were received with too little appreciation on the part of the anatomists. There was actually a certain amount of criticism by certain anatomists whose interests were insufficiently broad to understand the import of the papers, and to that extent the physical anthropologists had just grounds for their feeling. These expressions were not voiced in open meeting, but criticisms in both directions were the subject of corridor conversations. Hrdlička, for one, was bitter and a serious breach between the two associations was feared. The antagonism thus aroused persisted in some quarters."

From Dr. H. L. Shapiro (American Museum of Natural History):

"I recall that at one early meeting Hrdlička took me to one side and warned me in a very fatherly and benign way for my own good to eschew statistics like a plague. Todd, of course, attended all those meetings and was always a colorful figure."

From Dr. W. L. Straus, Jr. (Johns Hopkins University):

"I do distinctly recall the first meeting of the AAPA at Charlottesville in April 1930. I also recall that I was scheduled for a paper, 'The deep foot musculature of primates.' Unfortunately, however, the meeting is one of mixed memories for me. For I was called home in the middle of it by the death of my father. In fact, I didn't even get

to give my paper. Yet I do recall, and quite distinctly, after the joint session, that I realized the need for the physical anthropologist to have a thorough grounding in all the disciplines of anatomy, and an understanding of some physiology.

“As I look back, it is difficult to realize that Todd and Hrdlička are gone from among us, that Terry and Morton are no longer active scientifically, and that Schultz is over 3000 miles away. I am now an ‘old goat’ myself, and a proper target for the youngsters.”

From Dr. Adolph Schultz (now Professor of Physical Anthropology at the University of Zurich, but at the time in the Anatomy Department at Hopkins):

“Our meetings were invariably full of fun and one always got new ideas, new friends and new jokes. They were all the more enjoyable, if there occurred a few good fights. Do you remember the meeting in New York, when Weidenreich talked about skulls of *dogs* and Hrdlička thought he meant *ducks*, and the two got into a violent argument which nobody could stop, for laughing?

“I recollect vividly that historic meeting in the spring of 1930, when C. Heuser, F. Lewis and I motored down to Charlottesville and argued whether the impending divorce of physical anthropology represented a loss or a gain for anatomy. During my earlier academic years I had taken it for granted that all anatomists and physical anthropologists in America were *one* happy family in which the latter were somehow treated (and liked) as children. In retrospect it seems to me that it was a good thing we did leave the ‘family’ to become adult and develop our own individuality but the first years of our independence were not always easy and carefree. We would not have separated then, and possibly not for many years, had it not been for Hrdlička, who was by far the most active spirit for independence or, rather, for recognition of physical anthropology as an equal science instead of as a subdivision of anatomy.

“As I recall, the actual birth of our society was preceded and induced by discussions among the few full-time and the many and most active part-time anthropologists, chiefly Hrdlička, Bean, Davenport, Danforth, Scammon, Terry, Todd, Gregory, Morton, and myself. The formal organization took place at an initial ‘Business Session’ and a later, second one in which a Constitution and By-Laws were proposed and accepted in record time. I might as well confess here that, though I was one of the four who hatched the original By-Laws, I had unsuccessfully opposed that dream of an ‘American Institute of Physical Anthropology’ for which 80% of the income was to be reserved and the income to be raised quickly by cheap \$25 life memberships. I favored, however, a distinction between active and associate members

and, especially, a class of benefactors. I remember how surprised and proud I was that immediately 84 charter members could be enrolled. Of these barely half are still alive and only about 10 are still active in our science.

"Most of this can be gathered from the Journal, but what has been left unrecorded (fortunately) are the gruesome obstetrical details of the session and banquet at which our little newly born society was still together with its big mother society.

"The late C. Stockard, who presided at that session, was known to anatomists as extremely critical and often very sarcastic in his discussions of the papers presented. He lived up to his reputation after the first paper on 'Old Virginians' by dear old Robert Bean by bluntly asking what was new and significant in it. The following two papers, by the eminent anatomists, Todd and Scammon, Stockard did not discuss, but he made unmerciful fun of Hrdlička's really very amateurish theory of 'typogeny.' After Morton's suave talk on foot disorders, which was a sort of first version of his later book, 'Oh Doctor, My Feet,' Stockard became simply devastating in his comments, which were painful to listen to. You can imagine how I felt when my turn came to climb on the podium, particularly in those days when I was even more shy than now! [According to the program Schultz preceded Morton, but perhaps the order was reversed at the meeting.] During 15 terrible minutes I did manage to present my facts on primate variability, whereupon Stockard, the versatile actor, heaped praise upon my trembling head and freely admitted that physical anthropology might become a science some time! I hasten to explain that Stockard knew, of course, that I was the last of 'Mall's men' and that he was one of Mall's first and most distinguished group. Furthermore Stockard knew that I was now a 'Weed Man' and Stockard and Weed were old and devoted friends.

"Before the anatomists' banquet, to which our society had already been invited, Stockard asked me to his hotel room. The glorious old guard of anatomists was there around a huge bucket of moonshine with a little orange juice and ice in it. Stockard announced that he was not going to ask Hrdlička, nor even the local host, Bean, to the speakers' table, but that *I* must represent anthropology. By the time that bucket was empty I sneaked to a table in the banquet hall as far away as possible from the speakers' table, praying that Stockard would forget me. At the last moment somebody (I suspect G. Corner) did manage to steer Bean and Hrdlička to the very end of the speakers' table. After Stockard had finished his presidential address and had introduced his newly elected successor, H. Evans, another pupil of Mall, he welcomed our newborn society with beaming benevolence and shouted across the

hall that he wanted 'that young anthropologist, Schultz, to talk about the ties between the two societies!' Well, my moonshine had nearly worn off, but somehow I did manage to make a speech about 'ties' and scientific cooperation. I mentioned that the anatomists' president, Evans, had once abandoned some monkeys at Hopkins which became of great help in my work and that their new secretary, G. Corner, had nobly assisted me in getting a full-grown, male camel at 5 A.M. for my colleague Huber's studies by chloroforming the brute after I had failed to lead it across town with my lasso, and some more of such anecdotes.

"Toward the end of the banquet Evans took over as toastmaster and did call on Bean and Hrdlička to speak. Whereupon the former praised the latter and the latter said 'he wished there were a Bean in every state to measure old-timers!'

"To put it all briefly, the only trouble was that out of the 29 mostly very good papers on our first program, some rather poor ones got in the joint session and by these Stockard tried to show that we were not yet ripe for independence.

"I doubt that dear, old Doctor Hrdlička ever realized how he, as our representative, had been snubbed. At any rate, it never dampened his enthusiasm and devoted help for his young society, and that we must always remember most gratefully."

The second meeting was held in December of the same year, 1930, at Western Reserve University, at the time of the AAAS meeting and in special collaboration with section H. Doctor Brash of The University of Birmingham was on the program telling of his studies of bone growth. The membership had increased to 109. There were two special addresses, both given by Hrdlička — one (on the Smithsonian Expeditions in Alaska) after the dinner which was held jointly with section H and the other, "Animal-Like Manifestations in the Human Child" given at 4:30 on the next afternoon. Also, at this meeting Doctor Gregory spoke of the African Expedition of Columbia University and The American Museum of Natural History. To return to Hrdlička for a moment, in addition to his after dinner lecture at the third and fourth meetings, he gave a special evening address, thus setting a pattern for the program to include a special address. This practice continued through the first 13 meetings (except for the 5th and 10th) under the announcement of "Special Public Address." Gregory, Todd, Hooton, Shapiro, Weidenreich, John F. Fulton, and C. R. Carpenter were among those shouldering this responsibility. The more recent meetings have utilized this time for the business meeting and smoker.

No meeting was held in 1931, the next calendar year, nor in 3 other calendar years, 1933, 1947 and 1953, each following a year during which both a Spring and Christmas meeting were held. Because of

the war no meeting was held in 1943 nor in 1944. Thus, in 27 years we have had 25 meetings: whereas, each has been an independent meeting, approximately half have been arranged to occur in or near the same place of the meeting of the anatomists; other societies with which we have been happy to claim kinship are section H of AAAS, the American Society of Mammalogists, the Union of Biological Societies, and the American Anthropological Association. Next year the meeting is to be held at the University of Michigan coordinated with the meeting of the American Society of Human Genetics.

At the third meeting, in March 1932, an exhibit was introduced into the program. Occasionally, since, we have had exhibits but never on a very extensive scale. Perhaps we should make more of an effort in this direction.

Adolph Schultz succeeded Hrdlička as president, then came Pearl, Hooton and Todd. Todd died shortly before the first meeting under his term of office and Hooton served as president pro tem. Then came Terry, Gregory and Krogman. Bill Krogman did so well that he was reelected for a second term. Stewart succeeded him admirably. Washburn came next and was the first president who had not been a charter member of the Association. In fact, he had been elected to membership at the 10th meeting. He was so lively that, after his term, the office reverted to the old timers again (Straus and your humble servant) — perhaps with the thought of catching our breath after the accelerated pace set by Sherry's exuberant youth.

The important office of secretary-treasurer is an arduous one and was established for a 5 year term. Those who have filled this dual post are: first, Morton for 5 years, then Shapiro for 5 years, Howells for 3, Washburn for 4, Lasker for 4, Earle Reynolds for less than one year, and now Larry Angel, who completes his 5th year with this meeting.

Our membership has increased at a continuously accelerating rate: almost 400 members this year. Thirty-seven states and 25 foreign countries are represented on our membership list. New York leads with 58 members; then come Massachusetts, Ohio, Pennsylvania and California; of the foreign countries, Finland has 7 members; Canada, England, India and Sweden each has 5, Denmark, 4. Deplorably, France, Germany, Italy, Norway, Scotland and Spain are not represented.

Among distinguished participants in our meetings from foreign countries have been Professor C. U. Ariëns Kappers in 1935 from the University of Amsterdam, and Dr. Robert Broom in 1937 from the Transvaal Museum, Pretoria. At this meeting we are pleased to have Dr. Kenneth Oakley from London; Dr. John Robinson from Pretoria; and Dr. Phillip Tobias from Johannesburg.

The 9th meeting was held in Pittsburgh in 1938. It was to this meeting that Professor Franz Weidenreich first came. And, it was here in Chicago, at the 16th meeting, that Doctor Weidenreich was presented with a Viking Fund Medal and Award by the president, Doctor Krogman, who had been asked by Doctor Fejos to represent the Foundation. This was the inaugural year for these awards in anthropology. The Wenner-Gren Foundation has seen fit to present this signal honor annually to the nominee chosen by the Association. Our second nominee was Hooton; Doctor Linton, representing Doctor Fejos, gave Doctor Hooton the medal at the meeting in Washington. Following this the awards have been made at a special dinner in New York given by the Wenner-Gren Foundation. Our next medalist was Schultz, then Gregory, Krogman, Coon, Straus, Stewart and Howells. Last month the tribute was paid to Professor Sir Wilfrid Le Gros Clark, Doctor Lee's Professor of Anatomy, Oxford University. Sir Wilfrid wrote to Doctor Fejos: "I need hardly say that I am deeply sensible of the honour which was conferred on me by the American Association of Physical Anthropologists, the more so because it is an honour widely recognized as of unusual distinction."

In conclusion, let me read Doctor Terry's predictions of the future course of the Association. Doctor R. J. Terry has been Professor Emeritus of Anatomy at Washington University since 1941 and continues to be active in the laboratory. Typically, he was more interested in the future than in lingering over the past.

"I asked myself what of the future? I shall, with trepidation, assume the role of prophet.

"It is unnecessary to predict the continuing encouragement our organization will give its members for the zealous gathering of facts, a duty that will cease only when the science of PA ends and that, let us hope, will be — *never*. I see our association faithfully continuing to promote research toward the solving of old problems; giving service to ethnology; enriching the history of mankind, dating its progress by the new techniques. I envisage the AAPA continuing to cultivate investigation of man's evolution in the surge of keen interest aroused by the recent discoveries of Dart, Broom, Weidenreich and others; and in the search for the provenance of homonid types.

"Emerging interest and activity, I see, in exploring fields as yet but little noticed, promising rewarding discoveries; for example, the methods of physical anthropology applied to the fetus at different ages and of different races; their use in seeking to interest some of man's hereditary deformities; functional defects of mind and speech will claim more attention by the physical anthropologist in seeking to close the gap in our knowledge of man's evolution up from the ape.

Expansion of activity in the experimental field and in the give-and-take relations with genetics will come about. Growing interest is evident in the chemistry of the body in the search for criteria of anatomical and anthropological significance. This path of pursuit is in conformity with the tendency for all roads of biological research to converge toward the domain of chemistry.

"The AAPA will continue to aid the medical profession and life insurance statisticians for whom bodily proportions are significant. Our association will continue to give aid to the armed forces. I foresee its increasing influence with other scientific organizations toward establishing human relations in international comity. Perhaps with the broadening of the field over the years there may be sections of the AAPA established, united in an Institute of Physical Anthropology, an object, I believe of Doctor Hrdlička's. It will perfect its special disciplines, while maintaining bonds with fellow organizations.

"Some remedy must be found for curbing the tendency to multiply meetings of scientific societies before their death from lack of work to present and discuss. The thought appalls me of substituting radio and TV for friendly contacts and stimulating discussion. With increase in number of those working in physical anthropology, the many problems connected with publication must be solved.

"In conclusion let me remark that since there are many angles in the structure and numerous directions of functioning in an organization such as ours, pages would be needed to do justice in predicting its future. So I ask you to accept these notes as a mere outline drawn from a host of thoughts. This octogenarian finds happiness in his memories of meetings past and is proud of having had, with his colleagues, a part in supporting Aleš Hrdlička, who started this Association that hitched its wagon to a star and has won distinction in pursuit of the proper study of mankind."

BUSINESS MEETING, APRIL 6, 1956

President Trotter opened the agenda by announcing the appointees to committees for the coming year: Nominating Committee: Dr. W. W. Greulich (chairman), J. L. Angel, F. C. Howell; Viking Fund Award Committee: C. W. Goff (chairman), W. W. Howells, T. D. Stewart, W. L. Straus, Jr., S. M. Garn, M. S. Goldstein, and F. Thieme; Auditing Committee: E. C. Sensenig and N. C. Tappen; and Resolutions Committee: J. B. Birdsell, G. E. Erikson, and R. M. White. (After the meeting the president appointed Dr. C. S. Coon to succeed W.

W. Howells as one representative to the AAAS with a term extending to December 31, 1957, the other representative being J. L. Angel [term ending December 31, 1956], to be succeeded by F. Thieme.)

The minutes of the 24th annual meeting were approved as printed (*AJPA*, n.s. 13: 373-401, 1955) with Doctor Stewart's amendment that abstracts not be printed when the author had not presented the paper in person. The Secretary reviewed the membership curve: 1930, 84 and 109; 1942, 153; 1952, 300; 1956, 360 plus 44 candidates as follows. These approved earlier by the executive committee and now submitted to the members for ratification:

Charles L. Brace	James B. Hamilton	Alexander Ricciardelli
Milton R. De Lucchi	Rodger Heglar	Tulika Sen
Richard D. Givens	Hilel Notkovich	

Approved by the executive committee on April 5, 1956:

Roy M. Acheson	Lester Firschein	Betty L. Pope
Milton Alexander	Theodore C. Greene	Joan Nellie Popoff
Janet K. Arcuni	Kazuro Hanihara	Jack H. Prost
Virginia Avis	Arthur F. Halloran	Idell Pyle
James T. Barter	Phyllis J. Jay	Saul H. Riesenbergs
Renée Menegaz Bock	Arnold H. Kaplan	William T. Ross
John Buettner-Janusch	Martti J. Karvonen	Bernard G. Sarnat
Grace L. Cocke	Maxine R. Kleindienst	Miguel Antonio Schön
Glen H. Cole	Gretchen R. Krause	Ivar Skarland
Philip J. Epling	John McConville	Patricia Thompson
Jeremiah F. Epstein	Aloysius I. Miller	Phillip V. Tobias
Frank Falkner	Charlotte Otten	Richard W. Young

All were elected to membership. The Secretary expressed the regret of the Association in the death during the year of four of its members: Dr. Armando W. Angulo, Dr. Kurt Bröste, Dr. P. B. Candela, and Dr. John D. Ellis.

Opening a discussion of the position of the Association in relation to current race propaganda the Secretary read the executive committee's statement as a basis for further action: "Having received and read in the PA Newsletter the statements by Dr. John Gillin (of the University of North Carolina) on the absence of scientific proofs of innate superiority of any race, as quoted in the Daily Tar Heel, Chapel Hill,

March 8, 1956, the members of the AAPA meeting in Chicago on April 6, 1956, affirm that Doctor Gillin has presented the scientific position of professional anthropologists with clarity and accuracy."

Amidst qualifications that this scientific society could not pass judgment on any political matter (Coon and Thieme), that Gillin's quoted newspaper statement was not quite accurate since there have not been "hundreds of investigations" bearing on racial superiority (Spuhler), that it could be adopted unchanged (Tappen), and that the statement was unclear as it stood (Howell) and ineffective (Gavan), two general feelings emerged: that the Association should back a man in a difficult position asking for his society's support (Cobb, Coon, Howells, Howell, Gruber, Thieme, Aginsky, etc.) and that we should stress the lack of anthropological data which might justify racial discrimination (Washburn, Greulich, Spuhler, Kraus, etc.). Brozek pointed out that this hydra-headed subject of discussion raised (1) the question of what we can do to help John Gillin, (2) racial and ethnic discrimination as a social phenomenon, and (3) the need for a scientific statement with proper definitions on the subject of biological superiority versus inferiority. At this point at Lasker's suggestion the president declared the meeting a Committee of the Whole in order to review Gillin's statement reproduced on the front page of the 1955-56 PA Newsletter (from the Daily Tar Heel for March 8, 1956) and to draw up a resolution.

Doctor Bertram Kraus, editor of the Newsletter, read from the Newsletter, as follows:

Assertions that science has proven the Negro race inferior to the white race are untrue, Dr. John Gillin, Professor of Anthropology, said yesterday.

"As a professional anthropologist I must simply state that science has proved no such thing," he said in answer to the question of anthropological and genetic inferiority in the Negro race.

The statement refuted many points advocated by Dr. W. Critz George of the University Medical School faculty. George is president of the Patriots of North Carolina and an opponent of integration.

Doctor Gillin did not specifically mention George in his statement, although the issues explained are those mentioned by the Medical School professor.

Gillin explained science has shown that all living human beings are members of a single zoological species, *Homo sapiens*. "But, despite hundreds of investigations, no conclusive evidence has been offered of superiority or inferiority of any of the races . . . with respect to their innate psychological or cultural abilities or potentialities."

The statement pointed out that "it is, of course, conceivable that at some time in the future unquestionable scientific evidence of inherently 'superior' or 'inferior' racial psychological and cultural abilities may be produced."

"Until such a time arrives," commented Doctor Gillin, "nothing can be gained by basing discussions of segregation and other aspects of race relations upon misapprehension or misrepresentation of the findings of physical anthropology, race psychology, and human genetics."

Moral issues are raised, said the statement, by deliberate misrepresentation of the scientific position in which no responsible discussants wish to become involved.

Gillin also noted the practical dangers of policies or positions based upon ignorance or inadequate understanding of scientific facts.

He cited the beliefs "not so long ago" that the Japanese were "inherently" incapable of mastering military aviation because of their "slant eyes" and "alleged near-sightedness."

"Ignorance and perversion of scientific facts are always self-defeating in the long run," said the paper.

Doctor George has said that modern "scientific method" was first produced in societies predominantly (*sic*) white. Gillin pointed out that "the record does not demonstrate that such leadership in science was due to any innate characteristics of the white race, but rather that it was the result of a very complex combination of factors of non-biological nature, often lumped together as historical accidents."

Gillin also closed his paper by saying "it would seem that, from any rational point of view, whatever policy is eventually worked out with respect to race relations in the public schools or elsewhere should, in the interests of all concerned, take these truths into consideration."

After vote of the Committee of the Whole to support this approach the meeting was reconstituted and Dr. W. M. Cobb moved passage of the following resolution (seconded by Garn):

"The members of the American Association of Physical Anthropologists meeting in Chicago, Illinois, on April 6, 1956, affirm that they know of no evidence that any group is inferior to any other group by virtue of race. They support Dr. John Gillin in his recent position in this respect."

This resolution the members passed overwhelmingly.

Taking up our relations with other organizations the Secretary pointed out that the AAAS (in which Howells and Angel have represented us) will meet next Christmas in New York City. There Section H under chairmanship of Margaret Mead (Gabriel Lasker, Secretary) will hold a symposium on Man in the Tropics and jointly with the American Institute of Human Palaeontology will commemorate the 100th anniversary of the discovery of Neanderthal man. As chairman of our committee to the NRC (Stewart and Garn members) Dr. Russell Newman will report on tomorrow's NRC meeting at the Sunday afternoon session of the panel discussion of identification. Representatives appointed for the 5th session of the International Congress of Anthropological and Ethnological Sciences (Philadelphia, September 1-9, 1956) are Dr. L. C. Eiseley and Dr. W. W. Howells. At the First International Congress of Human Genetics in Copenhagen this summer Dr. W. S. Laughlin will represent us. The local committee of the American Association of Anatomists, which will meet next year at the University of Maryland on April 17-19, has invited us to share in this organization's Sesquicentennial Celebration in Baltimore, Maryland.

Our representative last summer at the Sixth International Congress of Anatomists, Dr. William L. Straus, Jr., submitted a short but detailed report on papers given at the Paris meetings and on the advantageous revision of the Basle anatomical nomenclature; in the absence of Doctor Straus his report has been filed with the Association's records.

Doctor Gabriel Lasker read a brief account of the Third Teaching Institute of the Association of American Medical Colleges, held at Swampscott, Massachusetts, October 18-22, 1955 under the joint title "Anatomy and Anthropology." At this meeting our subject was presented in its relation to medicine by a panel under chairmanship of Dr. W. L. Straus, Jr., including Greulich, Garn, Angel, Paul, and Lasker, who was our group's organizer and representative on the AAMC Topic

Committee (cf. Sympósium on anthropology and medicine at AAPA 24th annual meeting, *Proceedings AJPA*, n.s. 13: 391-393, 1955). Lasker analyzed results of interest to us in the AAMC's 271-page "Questionnaire Analyses" showing the answers given by adequate samples of medical students, teachers, and deans of the 93 medical schools in North America. He showed that a majority agree on the desirability of including in the medical curriculum such subjects as growth, variation, human genetics, but with somewhat less stress on human evolution. As a stimulus for candidates for the Ph.D. degree in physical anthropology and for their teachers, he mentioned the need for broadly trained teachers of human anatomy in medical schools.

Doctor Montague Cobb reported for the Constitution Committee appointed by Doctor Trotter (Cobb, chairman, Cummins, Greulich, Lasker, M. T. Newman), noted that any proposed change in the constitution or by-laws must be presented in writing by five members at the annual meeting preceding the deciding one (paraphrasing Article VII), and duly submitted the revised constitution. Doctor Trotter said that she had asked for a restudy since the present constitution, with revisions of various by-laws in 1940, 1943, and 1953, is confusing on several points. "As a result of several long discussions," Doctor Cobb continued, "the committee has spelled out more precisely the operations for nomination for office, election of members, meeting of executive committee, program of meetings, and editorship of the *Journal*, which is the property of The Wistar Institute and the organ of the Association. The Wistar Institute, therefore, appoints the editor for a 6-year term and four associate editors for overlapping 4-year terms (cf. *Proceedings of 13th annual meeting, AJPA*, 29: 313-314, 1942). We now recommend that the executive committee of the AAPA shall first nominate a candidate for editor, subject to approval by the membership."

The Treasurer submitted the following report, followed by that of the auditing committee; both were accepted.

REPORT OF TREASURER—FISCAL YEAR 1955-1956

United States Savings Bonds (Series F), maturity value	\$2,000.00
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Bank balances on April 1, 1955

Savings account in Fidelity-Philadelphia Trust Co.	\$3,437.82
Checking account in Fidelity-Philadelphia Trust Co.	705.09

Receipts:

Annual membership dues	\$2,314.00	
Postage paid by foreign members	16.80	
Sale of Studies	6.00	
Registration fees 1955 (after cash outlay) .	53.87	
Refund of Newsletter mailing expenses	20.00	
U. S. Savings Bond due (no. D161696F) ...	500.00	
Interest on savings account	34.38	
		\$2,945.05
		<hr/> \$7,087.96

Expenditures:

To Wistar Institute (subscriptions)	\$1,628.50	
To Wistar Institute (Proceedings)	97.54	
To Bertram Kraus (Newsletter)	125.00	
To Hotel Bellevue-Stratford (Smoker)	44.80	
Secretarial expenses	140.28	
Foreign members mailing costs	20.50	
Bank, foreign exchange charges .....	.85	
		\$2,057.47

Bank balances on April 2, 1956

Savings account in Fidelity-Philadelphia Trust Co. ...	\$3,472.20
Checking account in Fidelity-Philadelphia Trust Co. ...	1,558.29
	<hr/> \$7,087.96

Audited and found to be correct

April 6, 1956
N. C. TAPPEN
G. K. NEUMANN
Auditing Committee

Respectfully submitted

J. LAWRENCE ANGEL, Treasurer
April 2, 1956

The Treasurer declared the intention of investing the money in the Savings Account in government bonds or other securities; following the meeting five \$1,000 Bonds, Series J, were bought at a cost of \$3,600.00.

Having discussed editorial problems and policy earlier, the Editor of the Journal, Dr. S. L. Washburn, reported only that Dr. W. S. Laughlin was chosen as the next new Associate Editor and that favorable comment on the new Book Notes, as well as Book Review section, both edited by Dr. Fred Thieme, had been received.

As usual, comment on the Newsletter stressed rather small numerical participation of members in submitting news and bibliography. Several quoted compliments on its form and content, Dr. W. M. Cobb moved appropriation of \$125 for its continuation next year, and its editor, Doctor Kraus, noted the value of better exchange of information with foreign colleagues which would be possible by earlier scheduling.

The Secretary reported that through the good offices of Dr. F. Thieme the University of Michigan has invited the AAPA to meet at Ann Arbor, Michigan, on Friday, Saturday, and Sunday, April 12-14, 1957, together with the American Society of Human Genetics.

Doctor Robert M. White reported for the Resolutions Committee:

1. Be it resolved that the Association express its gratitude to the Department of Anthropology of the University of Chicago for its hospitality. Doctor Sherwood L. Washburn, Dr. F. Clark Howell, Mrs. Betty Pope, and other members of the local committee deserve our especial thanks for their contribution to the success of this our 25th annual meeting.

2. Be it further resolved that the Association again express its sincere thanks to Dr. Paul Fejos and the Wenner-Gren Foundation for their continued support of physical anthropology both here and abroad, and especially for their sponsorship of the supper conference at this meeting.

3. And, whereas the Association has lost four of its members, A. W. Angulo, K. Bröste, P. B. Candela, and J. D. Ellis, be it resolved that the Association extend its sincere sympathies to the bereaved families.

Respectfully submitted,

ROBERT M. WHITE
JOSEPH B. BIRDSELL
G. E. ERIKSON

As chairman of the Nominating Committee Dr. T. Dale Stewart (assisted by Howells and Lasker) announced the following candidates for office, whose election immediately followed the closing of nominations: for Vice-President, Dr. Joseph B. Birdsell; for Secretary-Treasurer, Dr. James N. Spuhler; for Executive Committee members, Dr. F. Gaynor Evans (to complete Doctor Spuhler's unexpired term) and Dr. William C. Boyd.

Under new business Doctor Brozek reintroduced the problem of definitions (raised earlier in connection with race), asking for a sharper bounding of physical anthropology and suggesting a truly current textbook of the field as one means to sharpen its focus. White and Washburn disagreed on the (low?) rating of human evolution in the field of medicine, Washburn pointing out the approach of men like DePalma, Bunnell, and Negus (work on shoulder, hand, larynx, etc.), and the further need ideally for paired journals in our field to cover both central and peripheral interests. Spuhler raised the difficulty of cost of textbook or journal expansion. Doctor Phillip Tobias agreed with Washburn and Spuhler, adding that as a South African working in human biology he was highly encouraged by the stand of the AAPA with reference to the science of physical anthropology.

The scientific part of the meeting included the following:

1. *Studies of the relationships between the areas of the articular surfaces of some finger joints.* R. Dale Smith, George R. Holcomb, John O. Fluegel¹ and A. James Lewis,² Department of Anatomy, The Creighton University School of Medicine.

The following joints obtained from the hands of cadavera were studied: the distal interphalangeal, the proximal interphalangeal, and the metacarpophalangeal of the index, medius, anularis, and minimus; and the interphalangeal, metacarpophalangeal and carpometacarpal of the pollex. The articular surfaces were exposed and photographed. The area and semiaxes were determined from the prints.

Analysis of the data suggested that the joints might be arranged in three classes. Class I consists of the metacarpophalangeal joints of the four medial fingers. Class II consists of the interphalangeal joints of all of the fingers as well as the metacarpophalangeal joint of the pollex. Class III is composed of only the carpometacarpal joint of the pollex.

The index numbers of class I joints were circa 47; 61 for class II, and 98 for class III. The distal component of the joint accounted for 32% of the total surface area of class I, 38% of class II and 49% of class III joints. The proximal surface of the joint is greater than the distal by 111% in class I, by 63% in class II and 2% in class III. The dorso-ventral semi-axes of the proximal component are two times greater than the distal in class I, slightly greater in class II, and similar in class III joints. The radio-ulnar semi-axes were similar for all three classes of joint.

¹ Lederle Medical Student Research Fellow 1954.

² Lederle Medical Student Research Fellow 1955.

2. *Anthropometry and biokinematics of the hand.* James T. Barter, Edward I. Fry and Bruce Truett, Air Force Aeromedical Laboratory.

The Anthropology Section of the Air Force Aeromedical Laboratory in conjunction with its contractor, Antioch College, is conducting a continuing and comprehensive study of the human hand. Results from the first phase of this study are reported herein.

The sample consisted of white, male Air Force personnel, a number of whom hold flying ratings. Comparisons were made between this sample and the 1950 sample of over 4,000 flying personnel to determine the degree of physical similarity of the two groups.

Both anthropometric and biokinematic data have been gathered on both hands for each subject. In addition to taking traditional anthropometric dimensions (hand length, hand breadth), a number of new measurements have been devised especially for this study (phalanx length and antero-posterior and transverse diameters). Roentgenological techniques were used for greater precision in locating anatomical reference points, which in turn allowed a correspondingly greater exactitude in determining length-breadth dimensions.

Biokinematic data were gathered by the use of strain gages bonded to steel bars. These data include grip strength for the total hand, as well as muscle force information on individual finger segments.

Means and standard deviations were computed for these dimensions, and correlations between the anthropometric and muscle strength data were also computed.

These data will furnish information for the design of Air Force equipment and clothing, but more importantly, they offer new data on a number of dimensions which previously have been ignored.

3. *Age changes in obesity.* J. Lawrence Angel, the Daniel Baugh Institute of Anatomy of the Jefferson Medical College, Philadelphia.¹

Of 124 undiseased obese white women studied with Dr. Karl Paschkis at Jefferson Hospital's Endocrine Clinic between 1944 and 1948 56 are "lost," five are dead, and one-third (42) have been re-studied after a 9½ year gap. Five deaths exceed expectation, but not significantly. Well over one-third of the returnee sample were really healthy in the 1940s as contrasted with one-eighth or less now; almost 25% now have cardiovascular-renal impairment and a further quarter are

hypertensive; one-tenth are now diabetic and almost one-third have developed gall-bladder disease since first studied; arthritis afflicts over half and varicose veins a smaller fraction.

The returnees (now aged 50) at 212 lbs. and 157 cm are very little smaller and lighter than the total sample, but have the same infantile body build and genetic and psycho-social background (AJPA, n.s. 7: 433-468, 1949). Surprisingly they are not heavier than they were ten years ago and show increase only in chest and abdomen depths, head length, etc., with incipient stature decrease and other expected changes. Serum cholesterol has risen 60 mg% to the upper 200s (208-268 mg%) and blood sugar 15 units just to exceed 100 (89-105). Blood pressure has risen from 136/86 to 141/93.

In general physiological and mechanical ageing processes are accelerated in the constitutionally obese as contrasted with morphological age changes. This study can give no proof that this ageing speedup results simply from increased cardiovascular load with the larger tissue mass, but the stair-climbing efficiency of the obese is diminished at least as much as that of hypertensives in comparison with "normal" controls.

¹ Follow-up study supported by N.I.H. Grant A-224 and continuations.

4. *Weight and body build of 25-year-old Army men.* Robert M. White, Quartermaster Research and Development Command, Natick, Massachusetts.

In an investigation of weight and body build among Army men, an analysis of the relationship between weight and size of frame has been carried out, utilizing data on a series of approximately 3550 25-year-old White Army separates. Three categories of frame size were established, based upon groupings of men having small, medium and large chest breadth and bi-iliac diameters. For each inch of stature, mean body weights were derived for men of small, medium or large frames.

5. *Experimental validation of roentgenogrammetrically determined volumes.*¹ Stanley M. Garn and Edward L. Gorman, Fels Research Institute for the Study of Human Development.

In the analysis of body composition through soft-tissue teleoroentgenogrammetry, the measured values are not ordinarily corrected since (a) enlargement is proportional in all parts of the scale and (b) relatively constant for a given part of the body. However, when volumetric analysis of the body constituents is planned, from soft-tissue roentgenograms, experimental validation of the calculated values becomes of importance. The present study is concerned with validation using a water displacement technique specifically designed for the purpose.

The basic apparatus consists of a vertically mounted 33 inch length of 12 inch air conditioning ducting, fitted with a reinforced bottom and equipped with a water inlet, drain, and a glass water-level gauge. Water at body temperature is pumped from a constant-temperature reservoir. In practice, the actual displacement of a 33 cm length of thigh is determined and this measured volume compared to the volume obtained by planimetry from a standardized A-P roentgenogram of the left thigh area.

The relationship between the gross thigh volumes and the computed volumes is fully rectilinear, and when fully corrected, deviations of less than $\pm 200 \text{ cm}^3$ in 5000 cm^3 may be expected. Measured volumes range from 2900 to 6315 cm^3 for subjects weighing 61 to 109 kg respectively. On this basis, the muscle volumes, the fat volumes and the bone as obtained by planimetry, may be expected to bear a close relationship to the amounts of these tissues present. Further validation of the muscle mass is now in process, using creatine-creatinine conversion as a biological index of the functioning muscle mass.

¹This research supported in part by A.F. 18 (600)-1566 contract Air Force Office of Scientific Research, Air Research and Development Command. The above statements do not necessarily constitute the opinions of the Department of Defense.

6. *Some effects of adverse environmental circumstances on skeletal development.* Roy M. Acheson,¹ David Hewitt, Celia Westropp and M. Neil MacIntyre, from Department of Social Medicine, Oxford University and Department of Anatomy, Western Reserve University. (Introduced by Gabriel Lasker.)

Greulich and his associates showed that the vicissitudes of war impaired the physical development of children in the Pacific area. In a longitudinal growth study of over 600 English children we detected a similar impairment when children from poor homes were compared with those from wealthy homes. Moreover if stature is considered in terms of skeletal maturity status instead of in terms of chronological age, it seems there is some absolute stunting of the poor children.

When the mean values for height (expressed against skeletal maturity status) for the English children were compared with those of the more prosperous Cleveland children, the Americans were found to be larger.

A third study of the English group showed that those children who had suffered an exanthem grew less in the year of their illness than children of the same age and sex who remained healthy during the same year.

In all these comparisons there was a constant difference in the response of the sexes to the adverse environment. Whereas the general retardation of growth and skeletal maturation was considerable in the boys, growth alone was significantly affected in the girls. Thus the absolute stunting appeared to be greater in the girls.

Currently a series of experiments is being carried out at Western Reserve on rats in an attempt to elucidate further the effects of disease and starvation on the development of the skeleton.

¹ Rockefeller Traveling Fellow in Medicine.

7. *The genealogical approach in human biology.* Burt W. Aginsky, The City College of New York.

During the testing of the genealogical approach in field research, it has been found that there is present an interrelation of the biological and the cultural.

Human beings recognize biological relationships and impose them in regard to marriage as compared with other animals. Thus, the kinship affiliations, that is, the cultural has some effect upon the resultant genetics. Genealogies which only include a history of marital relationships do not always include children resulting from extramarital relations.

Where sororate, levirate, cross cousin and intergenerational marriages are reported, rarely are all the marriages found in any particular family lineage and it is rarer for them to be found occurring in every generation. The informants state, for example, "There was no sororate because there was no wife's sister." When this was investigated in relation to (a) an expanding population, (b) a contracting population, and (c) a population which remains constant through time, various differences were found.

In an age grade, the difference in the number of generations going back 120 years, varied from individual to individual. There were two generations in a line of last born individuals as compared with five generations in a line of first born individuals.

Incest taboos which vary in the world from population to population, the traditional male and or female lineages and other matters which are commonly thought of as being "cultural" have been found to be as much a biological matter. A proper understanding of either requires an investigation of both.

Some implications regarding theoretical genetics will be presented.

8. *On certain morphological characteristics of criminals.* C. W. Dupertuis, Western Reserve University, School of Medicine, Cleveland, Ohio.

The somatotyping of a series of 233 young, adult, male criminals revealed a high percentage of cases with apparent relative weakness in the lower extremities. Many of the physiques examined appeared to be top heavy with well developed, muscular torsos and comparatively spindling legs. These observations were verified by a series of measurements taken on the somatotype photographs. The measurements were compared to similar ones taken on a group of 261 male medical students serving as a control series.

9. *Congenital hip dysplasia on the Fort Apache Reservation: some anthropological aspects.* Bertram S. Kraus, Department of Anthropology, University of Arizona, and John R. Schwartzmann, M.D., Tucson.

The incidence of congenital hip dislocation has been reported from most of the major populations of the world. In certain localities in Italy an incidence of 400 per 100,000 has been recorded. Recently the incidence of congenital hip dislocation has been found to be 6% (6,000 per 100,000) among the Salteaux Indians and 4.2% among the Laplanders. During the summer of 1954 a survey was conducted among the 3500 Apache Indians of the Fort Apache Reservation, Arizona. Clinical as well as roentgenographic examinations were conducted and over 700 individuals were blood-typed, measured, and interviewed for genealogical data.

The incidence of congenital hip dislocation is estimated conservatively at 6% and may be as high as 8%. Apparently related sub-clinical manifestation, such as subluxations and simple dysplasias, were more numerous. If all aspects of this disease are considered under the designation "congenital hip dysplasias," the incidence among the Apache may be as high as 30%.

10. *The genetics of chromatographic differences.* Allen S. Fox, Department of Zoology, Michigan State University.

Recent applications of paper chromatography to problems of taxonomy and population genetics (including the area of comparative primatology) have made desirable an understanding of the genetics of chromatographic differences. To this end, studies have been performed of the effects of heterochromatin (the Y chromosome) and of certain euchromatic loci on free, tissue ninhydrin-positive and ultraviolet absorbing or fluorescent substances detectable by means of paper chromatography in *Drosophila melanogaster*. Males possess a peptide and seven ultraviolet fluorescent or absorbing substances not present in coisogenic females. Females possess two UV-fluorescent or absorbing substances not observed in males. Eighteen amino acids, four peptides, and ten UV-fluorescent or absorbing substances are present in both sexes, but several of these exhibit quantitative differences between the sexes. The differences between the sexes is not attributable to the effects of the Y chromosome, since females with all or part of the Y are chromatographically identical with normal females and males lacking all or part of the Y are identical with normal males. The absence of dosage compensation suggests that the sexual differences are attributable to the genetic mechanism responsible for sex determination. The yellow locus has effects on neither ninhydrin-positive nor UV-fluorescent or absorbing substances. The three pseudo-allelic lozenge loci have no effects on amino acids or peptides, in spite of their known effects on the antigenic specificities of proteins. This and other work serves to suggest that the amino acids and small peptides of tissues are taxonomically more conservative than UV-fluorescent substances (pterins, etc.), so that the latter might be more useful at the infraspecific and the former at the supraspecific levels.

11. *The process of race formation: some genetic considerations.* Gabriel Ward Lasker, Department of Anatomy, Wayne University College of Medicine.

All the conditions for the significant influence of chance factors on race formation in man are present in contemporary human groups. They may well have been more pronounced previously. These conditions are that: (1) the social groups within which mates are sought must be small; (2) admixture into these groups must be relatively rare; and (3) individual groups must be susceptible to great increases in size without loss of their isolation. A thorough mathematical analysis is not now attempted. Nevertheless, on the basis of what little is known, one can hazard some quantitative guesses. (1) Random genetic drift might well occur in groups of up to 500 or so members. (2) Differences could be established and maintained in spite of immigration rates of the order of 20% or less. (3) They could become of major racial significance if such groups could multiply several hundred or several thousand per cent without loss of isolation. Examples of all these circumstances occur in human groups. Accidents of history have probably been important in the evolution of the races of man; racial differentiation need not depend on the natural selection of adaptive characteristics. Chance factors may determine race differences.

12. *Race as an evolutionary concept.* Leo Estel, Department of Sociology and Anthropology, The Ohio State University.

As an evolutionary concept the term race should represent an intermediate step in the formation of new species as a result of differentiation within a single polytypic species. The principle of an expanding and radiating population applies to man. The expansion in numbers of human beings has made possible the accumulation of a large number of relatively unimportant mutations. These are similar to the pre-adaptive mutations that have been an important part of organic evolution. Recurrent mutations are known in man so that the possession of a common characteristic or even a common facade of physical characteristics does not necessarily indicate a common recent origin. Man is an extremely mobile animal but occasionally a breeding group becomes isolated long enough to develop a complex of genetically inherited characteristics that distinguishes this group from other human populations. The mobility of man is such that these isolated groups are infrequently formed and seldom endure for any great length of time. The term race should be reserved for these isolated breeding groups. This use of the term race would leave a large percentage of the human population in a mixed or indeterminate category and obviate the necessity of placing every human being into a racial category.

13. *Hybrid variability and evolutionary analyses.* Joseph B. Birdsell, University of California at Los Angeles.

Racial anthropology has seldom explained its measures for testing population relationships, and has almost never been explicit about the assumptions underlying them. The field seems to have assumed primarily that likeness of form and measurement is directly proportional to the degree of genetic relationship. As a secondary working principle, it has assumed that hybrids will be intermediate in form and measurement between the parental populations. Thirdly, it has generally considered that hybrid groups will be more variable than the populations from which they have been derived. While there is reason to doubt the universal validity of all three assumptions, when applied to intra-specific populations, this paper is concerned with testing the last and least of these.

Both Howells ('36) and Trevor ('53) indicate that their imperfect evidence suggests that hybrids are no more variable than their parental populations, but Dunn ('54) in reviewing the latter, points out the unsatisfactory nature of the data, and concludes that the issue cannot be settled until anthropologists provide better materials.

For the first time, it is possible to provide data on a sizable series of F-1 hybrid males ($N=157$), and adequate representative series of both parental populations (Australian whites; $N=110$; aborigines; $N=578$). In twenty-eight standard body, head, and face measurements and indices, all taken by the same observer, the parental populations differ in their means significantly in twenty-five cases and differ by twelve times the P.E. of the difference in twenty-two instances. All three series are dispersed and free from any suspicion of in-breeding period. As Muller ('36) points out, population variability must be expressed in terms of the standard deviation, or some derivative function. In

the present study, the standard deviation, the coefficient of variation, and Morant's sigma ratio ('35) are used as measures of variability. Since the aborigines differ regionally in both metrical and morphological characters in a highly significant fashion, it has seemed wise, in addition to comparisons of total series of whites, hybrids and aborigines, further to compare three regionally-defined subseries of aborigines and the corresponding hybrids with the total series of white males. These four comparisons, based upon the three measures of variability, indicate that first-generation hybrids are no more variable than their parental populations, and may, in fact, show reduced variabilities. Thus for purposes of racial analysis, high variabilities cannot be taken as an indicator of hybridity. On the contrary, it is more likely to arise as a consequence of pooling numerous isolates that differ in their mean values.

14. *The utility of the cephalic index.* Donald Stanley Marshall, Peabody Museum of Salem, Salem, Massachusetts.

In recent years there has been a decline of interest in anthropometry, and a tendency to dismiss the significance of results of the skeletal measurements. This paper is an attempt to answer the direct question of the Social Anthropologist, "Of what use is the cephalic index anyway?" The analysis is based upon measurements taken of series of Polynesian crania which totaled over one thousand specimens, giving extensive areal comparative data. Results are analyzed in the light of contemporary series of measurements of living Polynesians. The utility of the data in pointing out the effects of historical change, indications of cultural areas, the effects of known cultural patterns, and potential conclusions as to migration patterns and racial relationships are discussed. Conclusions are drawn as to the definite utility of the index, together with the results of an analysis of the size of the sample which may be required for useful results.

15. *Growth of the frontal and parietal bones in white males.* Richard W. Young, Fels Research Institute, Yellow Springs, Ohio.

The present study was designed to investigate changes during growth and development of the individual frontal and parietal bones as seen in lateral skull x-rays.

The sample consisted of twenty boys from the Fels population for whom lateral skull radiographs were available at regular intervals from one month to sixteen years of age, and an additional group of 50 adult males for which one skull plate each was obtained. Measurements were made of frontal and parietal arcs and chords, and of bone thickness at nine points on each bone. Bone shape was calculated by the "shape index" methods, previously reported by the author ('56, *Am. J. Phys. Anthropol.*, n.s. 14: 59-71). The angular relationships of the frontal and parietal bones were determined by measuring the angles of the bregma-lambda-nasion triangle.

There is a relatively simple allometric relationship between the frontal and parietal bones. The value for "k," however, differs from that reported by Moss for comparable prenatal material. The "interphase" apparently occurs at birth or shortly thereafter. There is evidence that in some cases the parietal bone

may cease anterior-posterior growth before the frontal. The frontal arc cannot be accurately predicted if only the parietal arc is known. There is, nevertheless, a moderate positive relationship between the thickness of the two bones. The angle at bregma increases throughout the period studied, and the angle at nasion correspondingly decreases. The lambda angle is stable. The changes in angulation are closely related to the relative growth relationship of the frontal and parietal bones, as is demonstrated by the high correlation between the lambda or bregma angles and the ratio between the frontal and parietal arcs or chords. After the first year of life there is a progressive flattening of the frontal and parietal bones. The growth curves for arcs and for thickness do not coincide, with increase in thickness occurring at an initially slower rate, but continuing after anterior-posterior growth has ceased. The curves of change in angulation and of change in shape more closely approximate those for growth of bone thickness. The question of whether individuals hold relative position during growth was considered, as was the problems of autonomy in bone growth and of general factors influencing age changes in these bones.

16. *Analysis of Midland Man bone.* Fred P. Thieme, Department of Anthropology, University of Michigan.

Samples of bone from the Midland Man specimen, which is of Pleistocene age from Texas, were analyzed to determine the characteristics of some of the organic constituents. Tests for blood group antigens gave a clear 'A' reaction. Paper chromatography indicated the presence of several free and bound amino acids. Description of techniques and detailed results, comments about their reliability and a discussion of methods for improving both the quality and variety of information derivable from old bone was presented.

17. *The Upper Cave skulls from Choukoutien in the light of Paleo-Amerind material.* Georg K. Neumann, Indiana University.

With the accumulation of datable skeletal material from the earlier archaeological horizons from both North and South America, the Upper Palaeolithic cranial remains of five individuals from the Upper Cave at Choukoutien gain new significance as possible Proto-Mongoloid ancestral forms to the American Indian. Weidenreich's brief description, which erroneously attributed two separate mandibles to the two otherwise complete female skulls, unfortunately associated descriptive terms such as "Europoid," "Melanesoid," and "Eskimoid" with these finds. A detailed morphological and metrical reexamination of the available casts reveals that the particular traits, for which possible mixture has been invoked, are at the most only vaguely suggestive of Europeans, Melanesians, and Eskimos. All the traits in question appear repeatedly in various early American Indian populations and should be regarded as expressive of the natural variability of the group.

18. *Mycotic nature of arteriolar sclerosis in hospital patients.* James W. Papez, Department of Mental Hygiene and Corrections, Columbus State Hospital, Ohio.

Mycotic patches in arteriolar sclerosis in walls of small cerebral vessels teased in saline suspensions were studied under oil immersion, 970 \times , phase contrast microscopes. In past two years we have studied such patches in all decades of life to show their origin and stages of development. They arose inside of vessels from infested red corpuscles, or on outside from infested nerve cells. Late in first decade of mental deficiency they appeared as small dot-forms, or as ring-forms, often in rows, in thin vessel walls. In second decade they appeared as small mycotic cells (protoplasts) with central nuclear cores of brown or purple colloidal substance. From thirteen to twenty years, typical yellow, lipofuscin envelopes (of fat) were collected or synthesized around the mycotic cells. In third and fourth decades in psychotic patients, these late lipofuscin stages were common, but new stages occurred on terminal arterioles. In old patients, absorption of fat and reduction of fibrous tissue took place (changes described by others), but earlier stages were also seen in the capillaries. In psychotic patients mycotic patches were on outside of small cerebral vessels; they came from nerve cells. Atherosclerosis of larger vessels, coronaries and aorta were studied from scrapings or excised pieces. Photographs and drawings were shown.

19. *Identification based on hair.* Oliver H. Duggins, Department of Anatomy, Washington University School of Medicine, St. Louis, Missouri.

Human hair is readily distinguished from that of the Infrahominids. The three most important features in this determination are cuticular scales, type of medulla and pigmentation. Color, form and shape are of especial value in recognizing the racial affinity of hair. Distinguishing characteristics of hair of different regions of an individual are length, shape, tip characteristics, medulla and size. Personal identification based upon hair is still not an exact science. The method consists of comparing the questioned hair (or hairs) with samples from individuals most likely to have supplied it. At best, a hair may provide evidence indicating either that it *probably* came from a given individual or that it could *not possibly* have come from this individual.

An experiment to determine the degree of accuracy of this elimination process was based on a series of 5 tests. In each test there were samples from the heads of 100 different individuals of the White race; a few hairs had been extracted from one sample. Three examiners independently checked these few hairs against the 100 samples and selected the sample to which he believed the few hairs belonged. In three of the tests the correct sample was chosen. In each of the other two tests, the examiners readily eliminated 98 samples. Attempts to choose between the 2 remaining samples (one of which was the correct sample) resulted in each examiner choosing the wrong sample. Macroscopic examinations proved to be more helpful than microscopic examinations.

19a. *Anthropometric appraisal of body composition in the adult man.*¹ Josef Brožek, Laboratory of Physiological Hygiene, University of Minnesota, Minneapolis, Minnesota.

Within the anatomic frame of reference, estimation of the weight of the skeleton, muscles, adipose tissue and "viscera" remains the goal of physical anthropologists concerned with body composition as a facet of man's physique. In the absence of a validated set of the needed prediction equations, one can proceed by taking into account, in addition to age and sex, the variations in bony dimensions (stature, its vertical partitioning, skeletal width) and predict the individual's "standard" weight. The comparison of an individual's actual weight with such a standard, in the form of a ratio, indicates the relative amount of soft tissues (underweight-overweight). Determination of skinfold thickness enables one to add a second "dimension" of physique (leanness-fatness). A linear measure or measures of muscular development yields the third criterion of body development (muscularity).

Alternately, a measure of muscularity may be included in the equation for estimating the standard weight. In this event, and to the extent to which differences in body weight due to individual variations in skeletal size and muscular development (as well as, indirectly, in the weight of the viscera) have been accounted for, deviations from the weight standard will be a measure of an individual's adiposity. Body measurements on 238 Minneapolis firemen will be analyzed in these terms.

¹ The work was supported, in part, by a research grant from the Minnesota Heart Association and research grant H-10(C9) from the National Heart Institute of the National Institutes of Health, U. S. Public Health Service.

20. *Bipedal rats and mice, new laboratory animals.* Charles W. Goff and Walter Landmesser, Yale University School of Medicine and Newington Home and Hospital for Crippled Children.

By amputating the tail and the forelimbs just above the elbows of 3 day old Wistar white rats and D B A gray mice, using hibernation anaesthesia and tying the brachial artery, new bipedally adapted, laboratory animals are readily produced. The techniques were accomplished after some early difficulties. The work of Kiekmeier (1895), Fuld ('01), Colton ('29), and Slijper ('42), was repeated and extended. Conclusions demonstrated a ready adaptability of white rats with changes moving in the direction of man as a biped. These consist of a single footed gait, combined with a greater distance between hind feet; the femur becomes longer, tibia shorter, and the ankle breadth greater. A knock knee posture, with bending present in the upper tibia consistently followed the law of cubes. The toes spread farther apart, feet become plantigrade, skull shorter, spinous processes seemed to be less angulated, but the lordosis was no greater. An anterior scoliosis (for man a kyphosis) developed in the rat. Mice reverted to hoppers, directed in a devolutionary manner toward the marsupials (kangaroo). This adaptation, if ever a mutation of this sort takes place, is an example of Simpson's "Quantum Evolution" ('51), a big jump forward in the rat; a big leap backward in the mouse.

These animals are excellent material, rats in particular, for experimental postural surgery, scoliosis studies of a basic scientific nature (badly needed), and nutritional work as expressed in growth of an animal in the erect position.

To produce and keep for 12 months, each animal's cost totals 15 dollars. This includes entire overhead and constitutes a good basic determination when computing research financing.

21. *A comparative study of stresscoat and split-line patterns in mammalian femora.*¹ F. Gaynor Evans, Department of Anatomy, Wayne University and Charles W. Goff, Department of Orthopedic Surgery, Yale University.

Stresscoat patterns produced in mammalian femora by static vertical loading were compared with split-line patterns in the same bones. The bones were loaded in a 5000 lb. capacity testing machine with an accuracy of $\pm 1\%$. Tensile and compressive stresscoat patterns were produced by maximal loads of 240 lbs. (man), 800 lbs. (gorilla), 200 lbs. (chimpanzee), 175 lbs. (orang), 125 lbs. (baboon), and 730 lbs. (black bear). The stresscoat patterns arose from tensile strain in the superior aspect of the neck and the latero-anterior aspect of the shaft and from compressive strain in the opposite aspects of the bones. The stresscoat cracks lie transverse to the direction of the strain which is in the long axis of the bones. The stresscoat cracks are the visualized parts of tensile and compressive stress trajectories. If projected the tensile and compressive strain patterns cross each other at right angles in conformity with the mathematical requirements of stress trajectories. The split-lines are parallel with the long axis of the bone, do not cross and do not have the necessary requirements for stress trajectories. Split-lines are better interpreted as a modifier showing other factors which will be reported in a later study.

¹ This research supported (in part) by U.S.P.H.S. grant A-377(C5).

22. *Split-line patterns in juvenile and adult gorilla skulls.* N. C. Tappen, Department of Anatomy, Emory University.

Split-line patterns in the skulls of a juvenile gorilla (first permanent molar erupted) and an adult male gorilla show only minor modifications in the lower face region. The zygomatic region, frontal area, palate and braincase show substantial differences. Problems of interpretation of these differences and of split-line patterns in general are discussed.

23. *The structure and function of the laryngeal sacs of the Chimpanzee, Gorilla and Orang-outan.* Jane Enzmann, Department of Anthropology, Columbia University.

The anatomy of the laryngeal sacs of the ventricle of Morgagni is described in fifteen specimens (9 chimpanzees, 4 orang-outans, and 3 gorillas) varying in age from 10 days to adulthood. The development of these sacs varied from small herniations in the young to an enormous sac system in the adult. Certain features

of adult disposition were seen which provide evidence for a functional interpretation: (1) they exist in regions which in the human are occupied by discrete bursae, (2) they are present in the absence of bursae in regions normally anticipated, (3) they may communicate with the shoulder joint.

Despite the attention laryngeal sacs have received and the theories concerning their function, their true function is unknown. A new theory of function and mechanism of development is presented with a resume of existing information including: the normal anatomy of the ventricle and saccule in the infant and adult anthropoid and human; anomalous laryngeal sacs in humans and their etiology; and a discussion of theories of function of ape sacs.

The theory proposed is that the laryngeal sacs of these anthropoid apes are functionally a specialized type of bursa which develops rapidly during growth through brachiating activities associated with increased intratracheal pressure against a closed glottis, laryngeal adaptations for straining and arm efforts which in the human are mechanisms known to produce and enlarge laryngeal sacs.

24. *Blood groups of a gorilla, Jambo.* A. S. Wiener, E. B. Gordon and L. J. Goss, Serological Laboratory of the Office of the Chief Medical Examiner of New York City. (Read by title.)

25. *Evolution of the Bushman.* Phillip V. Tobias, Department of Anatomy, University of the Witwatersrand, Johannesburg.

The Bushman physical type shows a constellation of features which distinguish it from other major types, including Negroid and Mongoloid. Many of these features portray an infantile rather than an adult stage of somatic differentiation. In tracing the Bushman's descent, one observes these relevant points: (a) Although formerly more widespread in Africa, there is no evidence that the Bush type has originated elsewhere than in East, Central or Southern Africa. Explanations based on speculative immigrations from remote parts will therefore be avoided. (b) The earliest Bush remains date from the Middle Stone Age of Southern Africa: these are crania from two stratified cave deposits, Matjes River on the southern coast and Mumbwa, Northern Rhodesia. (c) All pre-Bush and pre-Negro skeletal remains from Southern Africa are of larger people than the Bushman. They comprise an earlier (Kanjera) group of Rhodesioid ("Neanderthaloid") character and a later (Gamblian and post-Gamblian) group resembling Bushmen on a larger scale.

It is suggested that the Bush physical type was a peculiarly African line of evolution, which can be traced back to the Rhodesioid group. Members of this group underwent two main types of change in Upper Pleistocene Africa: *differentiative* changes and *size* changes. These occurred in two stages: (i) *differentiative* changes occurred in some Rhodesioid peoples relatively early in the Gamblian, rendering them more infantile; (ii) *dwarfing* changes followed among some of the large pre-Bushman late in the Gamblian, leading to the emergence of the definitive Bush type.

SYMPOSIUM ON THE AUSTRALOPITHECINES

Chairman: S. L. Washburn, University of Chicago.

26. *The lower Pleistocene*. F. Clark Howell, Department of Anthropology, University of Chicago.

27. *Dating and tools*. Kenneth P. Oakley, British Museum of Natural History, London, England.

28. *The Australopithecines*. John T. Robinson, Transvaal Museum, Pretoria, South Africa.

29. *Mammalian taxonomy*. Dwight D. Davis, University of Chicago.

Discussion introduced by: Charles W. Goff, on locomotion; Albert A. Dahlberg, on dentition; Carleton S. Coon, on taxonomy; Phillip V. Tobias (for William L. Straus), on phylogeny.

PANEL DISCUSSION ON IDENTIFICATION

30. *Oral structures in the field of human identification*. James A. Brown and Albert A. Dahlberg, Department of Anthropology and the Zoller Memorial Dental Clinic, University of Chicago.

Dental restorations and eruption data have been the main source of oral identification in the past. Metallic shadowed collodion replicas and attrition have also been of significance. Many possibilities of broadening the scope within the field are offered by the geography of the palate (rugae) and the anatomy and characteristics of the units of the dentition. Three points to be considered in using these materials are: (1) Techniques and analyses in the dental field are more complex than those in the field of dermatoglyphics; (2) Identification can only be given in terms of probabilities; (3) Probabilities are compounded because there are so many independent factors such as those of accident, restoration, age, diet, cultural background and morphology.

Rugae are characterized by variation that readily differentiates identical twins as well as the right and left side of the same individual. These markings are not without minor change during life of the individuals, but they are minimal.

Dental identification has three major divisions of materials: restorative, morphological and accidental. The restorative aspect consists of general prosthetic constructions, and dental fillings. The morphological aspect consists of both genetic and somatic characteristics. The accidental aspect includes damages and pathological conditions that are acquired. Frequencies of many age level, sex and cultural factors of dental structures useful in ascertaining probabilities are available.

31. *Variation of the upper incisor tooth group.* Philip J. Epling and Albert A. Dahlberg, Department of Anthropology and the Zoller Memorial Dental Clinic, University of Chicago.

The greatest variation of form in the upper incisor tooth group occurs on the lingual surfaces and is expressed with the greatest emphasis on the unstable member of the group, the lateral incisor. Three major factors of unequal weights seem to contribute to the variations. They are: (1) the shovel-shaping factor, (2) the tendency towards irregularity and the lack of conservativeness in the cingulum, and, (3) the intrinsic factor of relative instability in the variable tooth of the group.

Varying intensities of these factors combine to produce different end results. They range from the uninterrupted smooth surface to the very prominent variety of shovel-shape with the extreme lingual projection of the lateral marginal ridges and also the associated anomalous forms of peg-shape, barrel-shape, irregular cingulum formation and dens in dente (tooth within a tooth). Presence of the shovel-shape factor is apparently necessary for the production of the barrel-shaped tooth. Frequencies of peg-shaped lateral incisors among Indians of the Southwest are very low (0-3%). The barrel-shape was noted in 11.9% of Maricopa females, and only 1.4% in Hopi females. Irregular cingula were found in 14.5% of Pima females, but in only 1.5% of the males.

32. *Analysis of the shovel-shaped incisor trait.* Albert A. Dahlberg, Philip J. Epling and James A. Brown, Department of Anthropology and The Zoller Memorial Dental Clinic of the University of Chicago.

The architecturally and functionally advantageous trait known as the shovel-shaped incisor is shown by pedigree and anatomical studies, probably as being controlled by a multiple-allele system. The following are pertinent conclusions derived from preliminary studies; (1) The depth of the lingual sulcus on the tooth is not a simple function of the "expression" of the allele system controlling this trait; (2) The depth of the sulcus is at least a partial function of the size of the tooth, and more specifically of its mesio-distal dimension, (3) Median ridges running incisally from the cingulum give variance to the actual depth measurement, (4) Variations in the cingulum tend to occur more frequently and to be of greater prominence in teeth manifesting the shovel-shaped trait, (5) Differing proportions of the crown are reflected in the conformation of the shovel-shape and in the depth of the sulcus.

Because there are so many factors involved in the shovel-shape trait, it can only be recommended at this time for limited use in comparative studies. Metrical description of the depth of the sulcus is more accurate and is preferred to the past visual evaluations, but it is not entirely definitive of the character in its multiple associations.

33. *Anomalies of the human masticatory organs.* Meyer Klatsky, Brooklyn, New York.

The masticatory and dental organs are subject to many anomalies or abnormalities of genetic origin. The incidence of 6 anomalies, which readily lend

themselves to study by means of skull examinations, were selected; namely, torus palatinus, torus mandibularis, supernumerary teeth, naturally missing teeth, reduced teeth, and impacted teeth. 8,323 human skulls of 25 geographically arranged groups were examined at the Department of Anthropology of the American Museum of Natural History, New York. The number, location, and character of these anomalies were studied and recorded.

Torus palatinus was found in 18 of these groups, both primitive and modern, totalling 482 palates. Torus mandibularis was noted on 89 mandibles of 11 groups of primitive peoples. The occurrence of supernumerary teeth was limited to 14 of both primitive and modern groups, totalling only 41 teeth. A total number of 947 naturally missing teeth, particularly third molars, were found among all the 25 groups examined. Reduced teeth were found in 20 groups, totalling 129 teeth. I found a total of 157 impacted teeth, mostly third molars and canines, in 19 groups, affecting civilized and primitive peoples alike.

I am indebted to Dr. H. L. Shapiro, Curator, and Chairman of the Department of Anthropology of the American Museum of Natural History for affording me the opportunity to examine the skull collections and take the necessary photographs, and for his invaluable aid and advice, which made this research possible.

34. *New landmark for measuring ilium, ischium and pubis length.* Lucile E. Hoyme, U. S. National Museum.

The innominate is of interest to anthropologists because it reflects both generic differences due to upright posture and sex differences associated with reproduction. These differences are due in part to different rates of growth in the ilium, ischium and pubis.

Ilium, ischium and pubis length, the axes of these bones, and the angles they form are all measured from a single point—the point where the three bones meet. A variation of a few millimeters in locating this point can produce considerable differences in the measurements obtained, and the resulting inter- and intrapersonal error reduces the value of the data for comparative purposes. In the case of the ischium-pubis index, an error in locating the point from which to measure could result in an incorrect sex determination.

A review of the literature shows considerable disagreement in locating the “ilio-ischio-pubic” point. Many of the landmarks used for locating the point are variable, and have little consistent relation to the actual lengths of the bones. To arrive at a better means of locating this point, I have examined a series of adolescent innominates where the ilium, ischium, pubis and associated cotyloid bones have not completely fused. This evidence shows that the traces of fusion within the acetabulum which would ordinarily serve as landmarks, are often unreliable, but that the site of union of the bones on the inner surface of the innominate is easier to locate. Therefore a new landmark, on the inner surface of the innominate, is suggested in place of the acetabular landmark.

35. *Notes on the sexual differentiation of the pubic bone.* T. D. Stewart, U. S. National Museum.

In recent years Washburn has focused attention anew on the pubic bone as an indicator of sex, pointing out that its elongation represents the maximum response in the bony pelvis to the action of female hormone. As he correctly states, most guides to sexing list only indirect expressions of this phenomenon; for example, the increase in the subpubic angle. However, since pubic elongation appears to result mainly, if not entirely, from accretion at the symphyseal end, does the additional bone have distinctive morphology? Also, since pubic elongation is associated with the function of reproduction and this function in turn affects the joint between the two pubes, have we been overlooking sex differences in symphyseal metamorphosis?

From this point of view skeletons of Eskimos and American Indians reveal a number of sex-distinguishing characters on and about the symphyseal face which are attributable in part to pubic elongation and in part to pelvic function. Although these features have been recorded by many observers, and most of them are mentioned in Todd's classic study of the symphysis, they are not widely used now in sex identification. This may be largely because Todd underrated sex differences in the symphysis and stressed the similarity of its metamorphosis in the two sexes. Also, since he had relatively few female skeletons to work with and a large proportion of these may have been nulliparas, he was inclined to deny that pregnancy and child-birth leave any permanent stamp upon the skeleton. On the contrary, the evidence suggests that in primitive peoples birth trauma often is registered in the symphysis.

36. *The Symphyseal Formula: a new method for determining age from pubic symphyses.* Thomas W. McKern, U. S. National Museum.

In determining skeletal age from the pubic symphysis, it is customary to use Todd's 10 typical age phases. Although these phases are supposed to represent the appearance of the symphysis over periods of time from 2 to 5 years in extent and thus ignore the variability within these age periods, surprisingly little effort has been made to improve on this system.

Confronted with the problem of analysing a set of 375 casts of pubic symphyses obtained by Dr. T. D. Stewart in 1954-55 from skeletons of American soldiers killed in Korea, and having in mind that the purpose of the analysis was age identification, a new system of formulation had to be devised. The solution of this problem has involved a symphyseal formula similar in many aspects to the formula used in somatotyping. In the symphyseal formula, it seems desirable to use 3 components divided into 5 chronological stages. By determining the age distribution of each component stage it is possible to translate any given formula into the most likely age at time of death with its probable error.

This paper will be limited to a discussion of the symphyseal formula, emphasizing its advantages over the more static phase system of Todd's.

37. *The application of strain gage dynamometry to muscle force studies.* J. T. Barter and F. D. Van Wart, U. S. Air Force.

1. The application of strain gages to muscle force dynamometers is relatively new and as yet not fully exploited. Some investigators have exhibited considerable ingenuity in designing apparatus to measure biomechanical phenomena. The Anthropology Section of the Air Force Aero Medical Laboratory is currently carrying on a series of long range studies utilizing strain gage dynamometry. A brief descriptive resumé of these applications has been presented.

2. Although various methods of calibration may be utilized, certain inherent errors exist in each. A comparison of static and dynamic methods of calibrating strain gage dynamometers has been discussed. Certain recommendations for calibration techniques were made.

3. The advantages and disadvantages of various methods of recording the output from strain gage circuits has been described with suggestions for the most practical applications.

4. Capabilities and limitations in the application of strain gage dynamometry have been described and evaluated in the light of current research applications in progress here and overseas.

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AN EVALUATION OF POLYNESIAN CRANIOLOGY

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TWO FIGURES

INTRODUCTION

There have been numerous analyses of the physical anthropology of the Polynesian area. Most of these studies concern themselves with aspects of craniology. While some have been primarily descriptive, many analyses contain explicit interpretations as to racial mixtures, migrations, or both — as for example the studies by Shapiro ('33, '40) and Howells ('33). These findings are generally made on the basis of presumed variations between and within samples from individual islands and island groups. Such differences are frequently interpreted in the light of various "wave" theories, the most notable being that of Dixon ('23), and the latest that of De Young ('53). Others are based upon a presumed spreading out from a center in the Society Islands, as in Shapiro's essay ('40b). Apparently most workers have not concurred with the suggestion of the Editor of this Journal Aleš Hrdlička ('27-'28), to the effect that —

"The author is mistaken in attributing decisive weight to such reports as deQuatrefages', Vernau's, or Sullivan's. If he will take the trouble to look through the catalogue of Crania, U. S. National Museum, Number 1, 1924, Number 2, 1926 or Bulletin 62, Bureau of American Ethnology, he will find a great variety of anthropometric forms, but they mean infraracial variation, not foreign races. The notion that race can be determined from isolated skull measurements and indices has long been given up by modern anthropology."

Many theories have been based upon second-hand data, relatively small series of subjects, or attempts to collate such series as could be located in the literature. The most exemplary compilation is that of Wagner ('37). Field measurements on the living have been taken by a wide variety of workers, but the laborious statistical manipulation has fallen to the lot of a handful of devoted scholars. Analyses presently available are principally due to the efforts of Dr. R. L. Sullivan of the American Museum of Natural History, and his successor, Dr. Harry L. Shapiro, with the close cooperation of the Bernice P. Bishop Museum of Honolulu.

Few attempts have been made to compare data from the living with cranial series. One exception was Dunn ('28), who apparently considered cranial studies to be less reliable than measurements of contemporary groups of the living. He attributes certain obvious differences to variations in measuring techniques. Implicit assumptions have generally been made that living "full-blooded" Polynesians are representative of the pre-European Polynesian population. Few students have placed the data which they were interpreting within a cultural context.

The authors have been fortunate in being able to draw on past work of many other students, and both have recently studied large series of crania at first hand, utilizing techniques taught by the late Earnest A. Hooton. Snow worked over the cemetery group (Mokapu) from Oahu, Hawaiian Islands, which was excavated by Gordon Bowles and a University of Hawaii and Bishop Museum staff prior to the start of the Second World War. This Mokapu group, presumably from a single breeding population, contains the cranial and post-cranial remains of over 350 individuals. Marshall measured some 700 crania in various overseas museums and burial caves in the islands, throughout a two-year field survey of Polynesia. Both Marshall and Snow made a check study on the same series of Hawaiian crania and obtained a very low index of personal deviation.

We have only made a start upon our basic research. This paper is the result of a necessary pause to make preliminary interpretations and to revise our techniques and thinking. Only the more obvious aspects of the data will be discussed, and interpretations confined to the male crania in our series, plus a preliminary survey of the literature. In our estimation the results of the analysis of this relatively large series of Polynesian crania, together with those of the small comparative Micronesian and Melanesian series, sufficiently indicates the possibility of changing conventional views of Polynesian craniology to warrant immediate presentation of certain of our data. We also wish to make a concise reference to environmental and socio-cultural factors which we believe must affect any interpretation of raw metrical data, but which we consider to have been inadequately considered in previous analyses of Polynesian craniology. Generalizations we make in the strictural sections below are of general knowledge to Polynesian ethnologists, although they have not yet been fully utilized by physical anthropologists.

Environmental strictures

Although it is generally conceded that there is some relationship between geographic environment and the physical manifestations of the inhabitants of that environment, as has been so vividly shown by Coon ('50), it is probably not generally realized how variable such environment is in Polynesia. Much of the area lies within the tropical zone, and most islands can be divided into "high" and "low," but such categories are somewhat equivalent to dividing racial groups of the world into two sections — "white" and "colored." There is a vast difference between subcontinental, mountainous, cold New Zealand and small, hilly, steaming Upolu island in Samoa. Even greater is the difference between these two examples and the tiny, palm-laden strip of sand called Pukapuka. It is safe to say that few of the thousands of islands of Polynesia are closely alike in environmental conditions. This variation extends not only within island groups, but even to por-

tions of single islands, where a few miles of coastline may mark the difference between arid desert-like climate and the dankness of a tropical rain forest. Each of these support relatively separate breeding populations, as has been shown in cultural context by Handy and Pukui ('50).

Obviously such geographic variations produce dietary differences. The atoll dweller may be hard put to subsist on coconut juice and nut products, supplemented with fish and pandanus. However, the well-watered higher islands offer varied ranges of breadfruit, taro, banana, pig, fowl, sugar cane, and innumerable other products to supplant, or at least supplement, the fish and coconut diet — and this for a much more leisurely taking. Within individual areas there was also a historical change in diet. The early New Zealand Maori, the "Moahunter," originally ate the flesh of the now extinct moa and other fauna, which was later replaced by the abrasive fern root. In all of the islands, since the arrival of the Europeans, tinned meat, white bread, tea and sugar have markedly changed local eating patterns.

Socio-cultural strictures

The influence of diverse environments on the physical characteristics of the Polynesians were also accentuated by local variations of material prosperity, social stratifications and breeding habits. Within a single valley, in some areas, the leaders lived on the healthy and plentifully productive shore line, and the lower classes were forced up within the wet but less fertile interior. Protein rich foods such as pig, turtle and fish were frequently restricted to chiefs, and the commoners relegated to a less varied diet containing large amounts of starchy foods. Daughters of chiefs might live a secluded existence in special "bleaching and fattening" houses, while their commoner sisters did the backbreaking labor of the taro planter. Where chiefs sat on stools and at night lay their heads on wooden pillows, wives and commoners contented themselves with squatting on their hams and sleeping on the bare mats. In some areas these mats

were in direct contact with the pebbled floor, in others cushioned by inches thick layers of sweet grass. Children of the chiefs in particular had their heads manipulated by hand or bound with fabric to produce a desired flattening, whereas the commoners might be allowed to grow as nature saw fit.

All of the preceding customs varied from island to island, and to a greater or lesser extent from island group to island group.

Within the high islands the valley, and a wedge-shaped political segment which centered about it, was a breeding center; where in the atolls it was the individual islet, or even small sections of it. Needless to say, within this small breeding population was also socio-cultural selection. Regardless of temporary liaison, the chiefly families frequently allowed only offspring of advantageous unions to live. Daughters of high rank were less promiscuous in the granting of sexual favor than were their lower strata cousins, as Captain Cook and his contemporaries have reported in such detail. Even in post-contact times, European genes have been unequally distributed according to social class. Today, in travelling among the islands, one is struck by the fact that the European man who lives permanently with an island woman is generally mated to a person of fairly high rank.

Breeding populations shifted with the fortunes of inter-valley and inter-island warfare. There were also factors of deliberate migrations and voyages of conquest, as well as potential genetic drift through the effects of new social forms and factors such as castaways brought from other areas by storm. Occasionally virtual slaughter of valley populations occurred, and consequently a later "breeding up" of the few descendants to take similar revenge on the slayers of their ancestors. It is possible that the emphasis on fertility was the reason for the erotic theme of many of the religious rites. The basis of much of Polynesian art style rests upon a portrayal of the genitals in exaggerated detail, and in depiction of the actual act of copulation.

Another factor of genetic importance is the lack of significance of the nuclear family, with many children of a single mother commonly sired by differing fathers. This was further intensified by the extensive adoption pattern, whereby few children were reared by their biological parents. This is a major factor of the Polynesian kinship patterning, even today.

In isolated areas such as Easter Island and the Chathams there was little chance of casual genetic admixture. In other areas, such as Tahiti, mating would be with predominantly Polynesian people. Far over in the west, both Nuclear Polynesia and the Outliers would be able to breed with either Melanesian or Micronesian stocks, or both. This situation is reflected in the well-known data on blood types, presented by Shapiro ('40b). In Hawaii, and Eastern Polynesian in general there seems little doubt but what occasional drift voyagers from Asia, the Northwest coast of America, or South America could have brought in new genetic factors, although we have not as yet seen convincing evidence that such contact actually did occur.

Historical strictures

There are indications that the level of Polynesian population at the time of first European contact may not represent a maximum. Island after island has been found with extensive material remains of a former population, but abandoned by the time of European discovery—witness the Pitcairn scene described by Shapiro ('36). Within the valleys of Tahiti were also indications of pre-European decline.

Of utmost significance to our problem, however, is the almost unbelievable population loss in the first generations following European contact. By means of such factors as smallpox, venereal disease, the common cold, tuberculosis—as well as gunshot wound—the population through much of the area was reduced to a tenth of its former size. Some examples of depopulation are collated by Tessier ('53), Where in Tahiti the estimates of population soon dropped

from 200,000 to 18,000 and in small islands such as Ra'ivavae from 3000 to 80, in the Marquesas whole valleys were wiped out, and reverted to jungle. In the Chatham Islands, Mangareva and Easter Island hardly a family remains whose ancestors were native to the soil. This depopulation did not uniformly occur in either time or intensity. Nuclear Polynesia suffered less than elsewhere. In the Outliers the process has occurred only in this last century, and still is in progress. In such places as Ontong Java the population has decreased to a tenth of that of 1907, as Hogbin has reported in detail — whereas the loss process has been slowly reversed in Eastern Polynesia. It is notable that in areas such as Tonga and Samoa, where lesser depopulation occurred, and where the present degree of variability is least, this metrical stability is probably correlated to some extent with a comparative lack of subsequent genetic admixture.

Coupled with the marked and early decline in population was the introduction of foreign genes. Add to the Polynesian pattern of sexual hospitality, shiploads of English tars French marines, and Yankee whalers who had not seen a woman for a year! Set down many New Bedford whaling vessels to ride out the hurricane season in the port of a tiny Polynesian island! Add to this the fact that Irishmen, Cockney, Negro slave, Chinese cook, Portuguese harpooner, Italian refugee and others from the earliest European contact jumped ship to spend the rest of their lives living with the islanders. Physical types could hardly be expected to remain the same, particularly when with the sharp decline of population there entered in new alignments of power politics.

New social groups were formed — new breeding populations. There was a marked increase in island to island interchange of Polynesian genes. In hardly an island in the area was there not to be found, shortly after contact, fertile adults originating in a widely assorted group of other islands. Even today, month by month and with every trading schooner, populations are reshuffled. Dietary patterns rapidly changed,

with the introduction of bread, sugar, tea, canned corned beef, new fruits and vegetables. Crops shifted, the water table lowered, settlement pattern and work routine changed, along with clothing and housing design and other cultural variation which may have affected physique. Other such changes may have been the introduction of or great increase in such infections as tuberculosis and leprosy.

Constancy

In contradistinction to the above data, when thinking of Polynesian anthropology, we must consider two factors of overwhelming significance:

- A. Over the entire area, the largest area on earth, a single language was spoken.
- B. Over the entire area there was a common culture.

Technical strictures

In discussing the collated data on skeletal series and the living, it should be remembered that many of the differences — and possibly the similarities — possibly represent variation of errors in techniques or instruments. Few Polynesian anthropometrists have checked their techniques against a standard series, and the scholars represent widely varied backgrounds of education and experience. The materials themselves can lead to misinterpretation. The antiquity of nearly all the specimens is unknown. Cave material may represent different social classes of varying historical periods from beach materials. Widespread practice of slavery, as well as migration, and drift voyages, lead to intrusive material among that which might otherwise be thought to represent a single breeding population. Many crania are available, but there are few long bones or mandibles. In part, this is due to poor collecting, and in part to such cultural aspects as the use of mandibles for temple decoration, and the secondary interment of skeletons.

TABLE 1

Some morphological aspects of male oceanic crania

	NEW ZEALAND MAORI	CHATHAM IS. MORIORI	HAWAII	FIJI	GUAM
SAMPLE SIZE	150	27	25	27	13
<i>Form:</i>					
Ellipse	..	..	..	7	..
Ovoid	26	30	16	84	29
Spheroid	00.6	..	16	..	11
Rhomboid	72	69	68	7	59
Brisoid	00.6	..	..	..	..
<i>Brow ridge:</i>					
Trace	2	7	..	..	25
Small	14	18	24	30	22
Medium	52	51	44	38	44
Large	28	22	32	23	7
Very large	2	..	..	7	..
<i>Parietal boss:</i>					
Absent	2	..	8	07.6	..
Small	38	50	28	76	55
Medium	54	46	40	07.6	40
Large	5	3	24	02.6	3
<i>Mastoid:</i>					
Small	4	..	..	..	7
Medium	39	23	24	76	44
Large	53	61	52	23	48
Very large	2	15	24	..	..
<i>Lamdoid flattening:</i>					
Absent	23	42	32	15	29
Small	58	50	24	38	33
Medium	18	7	40	46	29
Pronounced	00.7	..	..	..	7
<i>Nasal profile:</i>					
Straight	3	..	5	15	4
Concave	14	46	26	30	92
Con/Cox	82	53	68	53	4
<i>Palatal shape:</i>					
Parab.	93	92	85	100	78
Hyper.	3	8	9	..	4
Ellipse	..	..	4	..	13
“U”	3	..	..	..	4
<i>Bite:</i>					
Over	42	37	75	..	23
Edge	57	62	25	..	76
<i>Rocker jaw:</i>					
Present	40	55	75	..	..
Absent	59	44	25	..	100

Morphological observation

The morphological study of Polynesian crania appears to be as important as many metrical and statistical analyses. Regardless of whether they be from New Zealand, Hawaii or Tahiti — from Tonga or Mangareva, and excepting only Easter Island — Polynesian crania appear to be remarkably distinctive. This is not to deny inter-island and intra-island variability, but merely to state that in its morphological totality, a Polynesian cranium distinctly differs from a Melanesian or Micronesian cranium. This total impression can be validated by analysis of individual characteristics, although the statistical results of such separate aspects as shown in figure 1 tend to obscure the marked peculiarity of the total configuration. However, we feel that data collated in this table amply indicate that our generalizations concerning overall cranial morphology are based on the considerable physical distinctness of the Polynesian series.

The most striking peculiarity of Polynesian cranial samples is the characteristic "rocker jaw." This phenomenon occurs in some 50% of all Polynesian crania. In such a mandible the inferior margin of the mandibular body is convex downward. As a result, the bone may teeter like a rocking chair if placed on a table top and depressed and released either on the chin or the top of the ramus. This is presumably a genetic characteristic or complex of the Polynesian group, for we cannot relate it to any presently-known factor of diet or environment which separates Polynesia from other Oceanic areas. The range of diet and environment found within Polynesia is too variable, and too similar to Micronesia to be considered characteristic. The rocker jaw has been seen in some mandibles from Melanesia, but its incidence is not known, and appears to be lower than among Polynesians. In all 13 mandibles from Guam this trait was absent, which indicates the possibility of relatively low incidence in Micronesia.

The "type" Polynesian male cranium has the rocker jaw, an exceptionally flat temporal area coupled with large parie-

tal bosses, which leads to a "rhomboid" form, a variable degree of flattening at lambda, marked nuchal muscularity, relatively sloping frontal area, large mastoids, and supramastoid crests, a prominent glabella and medium to large brow ridges,

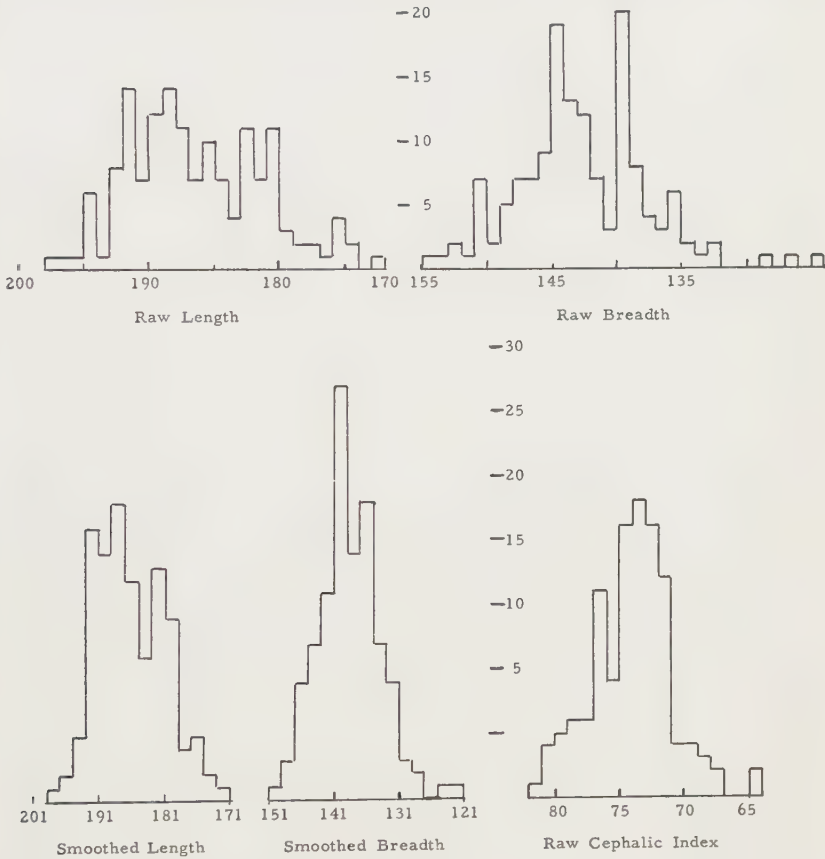


Fig. 1 Length and breadth curves, New Zealand Maori crania. (Sample of 150).

concave-convex nasalia, marked recession of the alveolar borders, and diminutive, impacted or absent third molars.

The Polynesian face, as reflected in those from Mokapu, Oahu, Hawaii, has a narrow forehead, but orbits, noses and faces of average proportions. The lower margins of the face

have typically rounded contours, with the Rocker Jaw so frequently present. Perhaps the most interesting feature of the face (next to the Rocker Jaw) is the flat-sided nature of the cheekbones. The Polynesian malars are typically large in size with considerable anterior prominence. On the lateral aspects, from the frontal processes down to the middle, the malar bones show a flatness which brings the surfaces parallel with the sides of the cranial vault. This bony "plane" must have given base to a rather flat-sided face contour, discernible on so many Hawaiian faces.

Nasal fossae with interesting double rounded sills to the lower margins of the nasal apertures, are common. Nasal spines are of a small to average size. Another common characteristic is the narrow-rooted nature of the nose bones. Both upper and lower jaws are large in size, show little anterior projection and contain teeth which show few caries. The dentition as a whole is characterized by its excellence, its close overbite, and the recession of the bony borders of the alveoli. In Hawaii, the shape of the palate frequently is flat-sided. From the canines back to the second and third molars, the teeth form a straight line. The Rocker Jaw, with its characteristic rounded lower border, frequently has an arch under the chin region, clearly seen in figure 2a. Usually there is a median and sharply pointed eminence to the chin. The jowl region shows little gonial eversion.

In comparison, Fijian crania are more gracile, longer, higher and narrower in proportion, definitely ovoid in form, with much smaller mastoids, possibly less facial prognathism, less overall muscular relief, particularly in the nuchal area, much smaller parietal bosses, and flatter temporals. Only two complete mandibles were available, but these do indicate the rocker jaw. A Micronesian series from Guam all lack the rocker jaw, show more prognathism, have notably smaller glabella and brow ridges, almost always have shallow concave nasalia and less protrusive nasal bridge, more vertical frontal area, smaller parietal bosses, larger and more ellipsoid palate, less crowded teeth with more cusps and a greater

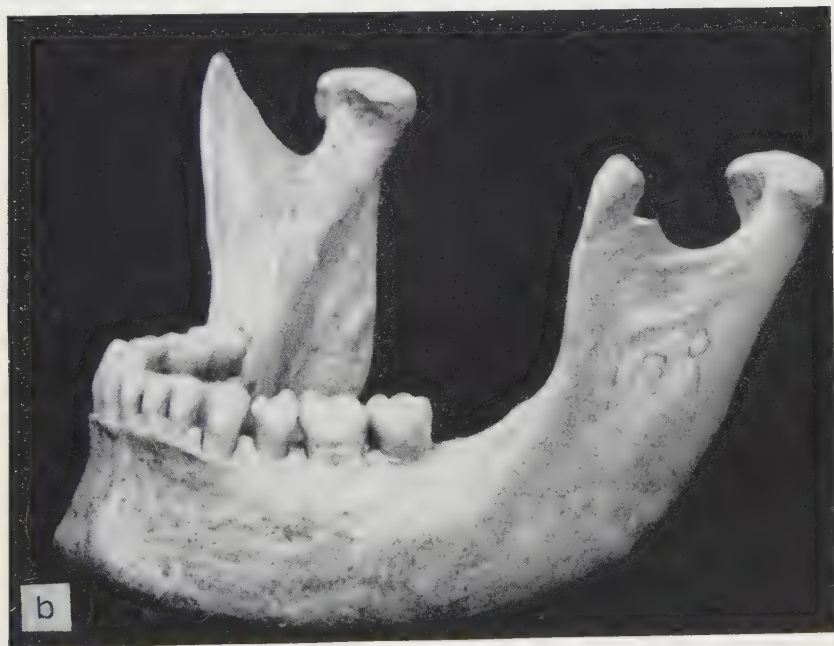


Fig. 2 New Zealand and Hawaiian rocker jaws.
 a. Maori male with typical mandible.
 b. Hawaiian female from Mokapu (H179) showing the pointed chin.

frequency of occurrence of edge bite. Fijian crania resemble Polynesian in the frontal area, including the brow ridges, as well as in the nasal profile, whereas Guamanian resemblance is not noticeable in morphological aspects, other than form.

Cultural effects show variations from group to group: Hawaiians show greater evidence of artificial deformation, whereas Guamanian crania indicate "tooth knocking" and betel chewing. The tooth wear pattern varies considerably. In Central Polynesia molars show little wear even in middle age, but in New Zealand the incisors are worn down to or beyond the gum line by early adulthood, and the molars are laid sidewise in the maxillae and ground down to a high polish by the stress and abrasive nature of chewing fern root. Caries may occur rarely in some non-worn down teeth, whereas the ground down molars lack caries but have numerous severe abscesses.

One of the most significant factors in our studies is that the "Moahunter" New Zealand group, presumably the earliest for which we have Polynesian cranial remains, already shows the highly diagnostic Polynesian configuration, and is quite close to the classic Maori in metrical aspects.

Preliminary statistical analysis

Our conviction as to the overall homogeneity of the Polynesians, as opposed to Melanesian or other Oceanic groups, rests primarily upon morphological configuration, as indicated above. However, this homogeneity is supported to some extent by metrical data. For example, the Polynesian males have a greater cranial capacity than any of the other oceanic groups (Hambley, '47), and the cephalic index of all Polynesian groups, other than Easter Island, appears to be above that of most or all Melanesian groups (Hambley, '40, '46, compared to data shown in table 2).

The following interpretations heavily rest upon the frequently over-worked cephalic index. We find the index useful, in that it appears to be particularly sensitive to areal

TABLE 2
Some measurements of male oceanic crania

SIZE OF SAMPLE	MARQUESAS		SOCIETY	CHATHAM (Moriori)		NEW ZEALAND (“Moahunter”)		NEW ZEALAND (“Maori”)		HAWAII (Mokapu)	TONGA		FIJI (Melanesia)		GUAM (Micronesia)	
	13	21		27	6	152	139 ¹	8	13		27					
Circumference	519.5	526.9	525.8	529.3	519.2	521	510.0	526.9	511.8							
Nasion-opis. arc	373.1	382.7	379.0	382.0	376.4	374	360.0	370.4	378.9							
Transverse arc	313.6	322.5	310.7	317.0	311.5	325	330.5	314.0	316.7							
Maximum length	186.5	188.5	189.0	191.0	186.8	184	174.9	192.6	180.5							
Maximum breadth	141.1	142.0	142.7	142.7	139.1	144	149.4	134.2	140.5							
Cephalic index	75.8	75.4	75.6	74.6	74.5	78.5	85.1	69.6	78.5							
Height	138.0	141.8	137.6	140.3	138.9	142	142.0	138.1	143.6							
Minimum frontal	91.9	96.0	95.0	95.8	94.4	95	97.8	96.5	96.8							
Bizygomatic	137.0	137.4	140.6	142.0	137.4	138	138.0	134.3	137.6							
Nasion-prosthion	73.6	71.7	75.0	78.8	71.1	71	71.3	69.7	71.9							
Basion-prosthion	107.6	104.8	103.4	103.3	101.5	103.0	105.3	104.7	100.4							
Nasal height	51.5	50.6	54.7	54.3	51.0	52	50.6	50.8	51.0							
Nasal breadth	25.8	27.5	26.2	25.0	26.1	26	25.8	26.4	26.5							
L. orbital height	35.0	35.2	36.2	34.6	34.6	34	34.5	34.3	34.8							
L. orbital breadth	41.0	41.0	42.3	42.0	41.2	41	42.0	42.0	41.6							
Interorbital	21.0	20.8	19.6	20.0	19.6	21.6	21.4	21.1	20.3							
Biorbital	98.8	101.3	102.8	100.5	100.3	100.0	104.0	101.4	101.4							
Palate length	56.6	55.8	55.5	56.7	54.3	55.0	57.0	58.3	54.8							
Palate breadth	63.8	63.5	64.1	67.3	62.2	63.0	64.8	64.1	66.4							

¹ Snow's and Marshall's measurements.

differentiation, as well as to temporal change, as indicated below. We also find it to be the most consistently accurate result of measurements between various workers, and to be a useful indicator even in very small series. For example, the Marquesas series of 38 males measured by Wagner gave a cranial index of 75.9, and the series of 13 by Marshall 75.8; the Hawaiian series of 56 measured by Wagner resulted in an index of 78.5, the series of 135 by Snow and Marshall in 78.5, and the series of 23 by Turner in 78.5. It is also felt that this index is a more useful comparative measurement than others such as raw length or breadth, for it would appear to be less influenced by gross size differences, which possibly are related to environmental or social factors.

Certain measurements, such as the interorbital breadth, nasal height and breadth, and orbital height and breadth are much the same through the entire area. Nevertheless, Fiji (representing Melanesia) differs from Polynesia in that the crania are grossly longer, narrower in both maximum breadth and in bizygomatic, with a shorter face and longer palate than any of the other groups measured by the writers. Guam is more nearly like the other groups, but the measurements' similarity to the Hawaiian series is at least in part spurious, due to the results of artificial deformation, which was practiced in Hawaii more strongly than elsewhere.

The dichotomy between Eastern and Western Polynesia, widely recognized by ethnologists on the basis of studies of material culture, social structure, and linguistics, is strongly reflected in the cephalic index. Tonga is more brachycephalic than any of the other groups measured, and this brachycephaly is reflected in the markedly lesser circumference, shorter nasion-opisthion arc, longer transverse arc, shorter maximum length, greater maximum breadth, higher cephalic index, and broader minimum frontal than any other group measured. This is all the more striking in that the most intense Tongan transculturative content was with Fiji, whose average cranial measurements represent an antithesis to the data from Tonga. However, these differences are also

reflected in data recently collated on linguistics and material culture by Marshall.

Within Eastern Polynesia, the central area shows extensive homogeneity in the cephalic index. The Peripheral Polynesian area of Hawaii, New Zealand, the Chatham Islands and Easter Island show expectable variations. The increased figure for Hawaii may in part reflect greater emphasis on artificial deformation practices. The Easter Island figures (Wagner, '37; Imbelloni, '51) are unaccountable, however, and the extreme deviation is also reflected in the general configuration of these crania. The homogeneity of Central Polynesia may well reflect the more nearly similar geographic environment, and the constant contact, both deliberate and accidental, between these islands and groups; whereas the Peripheral islands are not only markedly varied in environmental conditions, but are exceedingly isolated from the rest of Polynesia.

Perhaps more significant than areal variation is the temporal deviation which is clearly obvious from a comparison of our figures to those on the living (Sullivan, '21, '22, '23; Shapiro, '30, '33b, '36b, '40b). This difference is apparent in both raw measurement and indices. For example, the cranial index on Easter Island averages 70.1 or 71.2 (Von Bonin, Imbelloni), whereas on the living is given as 74.6 or 76.0 (Shapiro, Bormida); in the Marquesas crania average 75.9 or 75.8 (Wagner, Marshall), where the living are 79.4 (Sullivan); in Tahiti, crania measure 75.4 or 75.1 (Marshall, Quatrefuges), whereas the living are 84.96 (Shapiro); in New Zealand, the crania average 74.5 (Marshall), and the living 77.7 (Buck).

Only in Nuclear Polynesia do the crania exactly differ by the expectable two points from the living, for the small series of Tongan crania are 79.1 (Marshall), and the Tongan living 81.1 (Sullivan, '22). These figures relate to those available for Samoa (Sullivan, '21, '23). The data are the more striking in that Tonga was in close touch with Fiji, and there was a good deal of pre- and post-European intermingling — gen-

erally contributions of genetic factors by Tongan warriors on mercenary duty in Fiji. This may account for the great Fijian pre- and post-European deviation, from 65.4, 68.3, 69.6 in the cranial series (Flower, Krause and Marshall) to the 81.5 in the only series on the living (Howells, '33).

It is obvious from the preceding figures that two major phenomena occurred.

1. An expectable increase in variability between islands, due to different types of foreign admixture and varied degrees of transculturation.
2. An unexpected general increase in brachycephaly, well beyond the predictable increase due to flesh versus bone measurements. (The latter has been calculated by us at 2%.)

Acquaintance with historical and cultural data also indicates that where contact was strongest, and its effects most severely felt in depopulation and transculturation — such as in Tahiti — the change was greatest. This is in marked contrast to the Nuclear Polynesian area. The increase in brachycephaly is not predictable on a basis of morphological comparisons of the areas presumed to be more archaic than those settled later on (as in Tonga versus Tahiti), nor in the temporal comparison of our only "early" versus "late" series, the New Zealand Moa hunter and the classic Maori.

The temporal and areal changes and differentiation, as suggested above, are also borne out by studies of constancy and variation in linguistics, material culture and social structure.

The particular interest of the temporal changes in cephalic index goes well beyond the Polynesian field. Certain "socially minded" scholars have misused Shapiro's carefully detailed studies ('29, '36a) to support beliefs in heterosis or "hybrid vigor." The study rested to a large degree upon the comparison of the measurements on a series of living Tahitians, as representing the Polynesian side of the "hybridization." When it is realized that of all the Polynesian peoples the Tahitians have probably changed to the greatest degree

in body type (if we may infer from the cranial data to the rest of the organs) as in language and culture, then it is obvious that those data from Pitcairn or Norfolk should be used by others as carefully as they are presented by Shapiro.

Inspection of the accompanying stack graph (fig. 1) of the Maori length, breadth and cephalic index reveals an obvious bi- or trimodality in New Zealand, which also occurs in such other measurements as the height of the nasal opening. It is tempting to tie this in with indications of material culture, art motifs, and the like, which suggest Melanesian admixture. However, the variations may just as well represent one or more other aspects such as a North or South island difference, social distinctions in "beach" versus "cave" burials, temporal variation or otherwise. Before even a tentative hypothesis may be made correlation manipulation on the basis of locality, type of burial, and the like, must be undertaken.

Relationships

Although we do not propose to discuss race relationships or migrations at this time, it does seem pertinent to comment briefly on the oft-mooted question of the relationship of the Polynesians to their neighbors. We agree with deYoung ('41) that the Hawaiians as a group are markedly distinct from both Melanesian and Micronesian groups. Although the metrical data might seem at first glance to relate Polynesians to Micronesians, the morphology points in the other direction. This is again born out by linguistic and cultural studies. At the same time such distinctions must not be overstressed to the detriment of recognition of obvious affinities. What similarities and differences of physical type are related to similarities and differences of environment, and what to racial antecedents, we are not yet prepared to say.

Basic problems

In all of this, however, we must not forget certain obvious and important problems. Primarily significant is the eternal

question of Easter Island. Extreme deviation in cephalic index is obvious, but the physical deviation is *not* correlated with as great a linguistic deviation. The total cultural configuration does vary to a marked degree from that of Central Polynesia, but this appears to be related to environmental limitations. Is this variation from Polynesian type due solely to genetic drift, under conditions of extreme isolation, or due to one of several hypotheses of racial "waves"? What is the difference between the environmental effect of *atoll* versus *high island*? Little or no cranial data from atoll groups are available, and the evidence of the series on the living is even more disturbed by present flux of variables than that from the high islands. What are the effects of social strictures? May these be determined by comparing cave with beach burial crania from the same breeding population area? Why do our data to date indicate that most adults died in their twenties, and most children at the period of the emergence of the first permanent molar? What is the relationship of cranial variation to normal (non-racial) deviation? What are the full effects of the various types of Polynesian artificial head-shaping practices? What effects did the fluid Polynesian kinship system have?

CONCLUSION

This paper raises many more questions than it purports to answer, but we do feel that points raised suggest the following:

1. There is a recognizable "Polynesian type" of cranium.
2. The peoples of Eastern Polynesia may have either split off from Western Polynesia a significant period of time ago, or the migrants were a selected group, for the crania to be metrically so divergent within the morphological similarity of configuration. The geographic distribution of Polynesian dialects has been analyzed by Marshall utilizing the method of glottochronology, and reveals somewhat comparable differences between the Eastern and Western areas.

3. Sub-types within the Polynesian area may be related to a complex of geographic, historic, and socio-cultural factors.

4. For purposes of historical analysis the study of Polynesian craniometry cannot be neglected in favor of a study of the living — *but*

5. Just as obviously, a study of the living will bring important results in increasing our knowledge of the results of race mixture, dietary change, and the like.

6. Where the suspected variables have changed least, the physical type has changed least.

7. In spite of the abandoning of the practice of head-shaping, and other cultural factors which might have tended to increase brachycephalization, the latter has in fact markedly increased. This is important in that due to the tremendous loss of population in the first period of European contact, we must assume that there was a survival factor in operation in favor of those few who managed to live. In this brachycephalization a manifestation of this unknown factor?

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AN EVALUATION OF THE PHOTO-METRIC CAMERA ¹

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TWO FIGURES

The measurement of the living or intact human body is one of the basic activities of physical anthropologists. The measurement of photographs, or "photogrammetry," of the body is a possible alternative, and its advantages and limitations have been discussed in a number of recent papers (Tanner and Weiner, '49; Dupertuis and Tanner, '50; Gavan, Washburn and Lewis, '52).

An important innovation in the photogrammetry of the standing human individual is the so-called "Photo-Metric" camera. This equipment is manufactured by the Photo-Metric Corporation, 3 East 44th Street, New York 17, N. Y. It is set up as part of a fixed installation of mirrors and electronic flash units. The mirrors are arranged so that 4 complete views of a standing human subject are concurrently visible as mirror images at the site of the camera: front, left side, rear, and overhead. One exposure of the film in the camera records all of these views at once.

This elaborate equipment was originally designed for use by clothiers in fitting garments. The manufacturer, however, envisioned its usefulness for scientific purposes, and has therefore installed three units at locations where research could be carried out. One is at the Department of Physical Education at Yale University (Blesh, Meyers and Kiphuth, '54). A second unit is at the U. S. Military Academy at West Point, and a third at the Adolescent Unit of the Children's Hospital,

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Boston, Massachusetts. The Director of the Adolescent Unit, Dr. J. Roswell Gallagher, was instrumental in arranging for its installation in one of the hospital buildings.

The Photo-Metric unit includes a camera with a motor-driven winding mechanism and a lens with a fixed aperture and focus. This lens is a Kodak Commercial Ektar with a full aperture of f.6.3, but which is set at f.8 for operation. The focal length is $8\frac{1}{2}$ " (21.6 cm). Near the camera is a fixed pedestal on which the subject stands to be photographed.

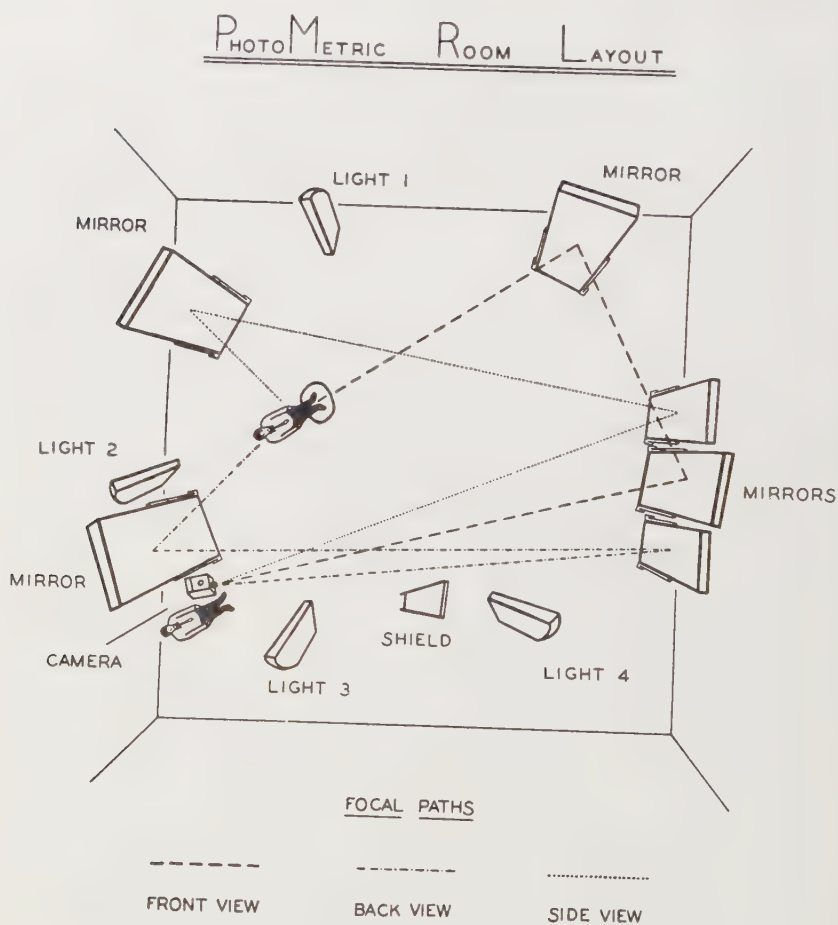


Fig. 1 "Photo-Metric Room Layout."

Around the periphery of the camera room are 9 mirrors, 6 of which are shown in figure 1. The mirrors are arranged so that the 4 images of the subject are simultaneously reflected onto the lens. Arranged between some of the mirrors are 4 synchronized electronic flash units.

By pressing a button on the camera, the operator sets off the flash units and exposes the film. Then the camera automatically winds the roll of film into position for the next exposure. This roll has a length of $17\frac{1}{4}$ feet ($5\frac{1}{2}$ m), and consists of Kodak Super-XX Panchromatic 70 mm film. One roll suffices for about 50 exposures.

The 4 photographic views of the subject are recorded on a single square negative, measuring 70×70 mm. The exposed film is processed by the Photo-Metric Corporation and returned to the user as negatives and as glass positive lantern slides. A retouched print from one such negative is shown in figure 2.

Unlike positive prints on most photographic papers, the glass lantern slide retains the exact dimensions of the body images as they were on the original negative. Where conventional contact prints are used for photogrammetry, such exactitude is only possible through the use of special waterproof base paper (Tanner and Weiner, '49).

Since the images on the glass slide are very small, a special projector and mirror are used to enlarge them to one-half life size on a ground glass translucent screen. The measurer is located on the side of the screen away from the illumination, so that no shadows dim his view or obscure his measurements. Vertical measurements are made with a horizontal wire which is rolled up or down by a manual control, and read off a vertical ruler on the side of the screen. Horizontal or diagonal measurements are read from a transparent plastic ruler held in the hands. In keeping with the enlargement of the images, these measuring devices are graduated on a scale of one-half natural size.

At the time of installation, the mirrors for the camera and projector are adjusted by means of a calibrated rod suspended

over the pedestal in the plane of focus. When the mirrors are correctly oriented and this rod is photographed, its dimensions on the glass lantern slide, as measured from the half-size projected image, are accurate to within $1/16''$ per $72''$, or

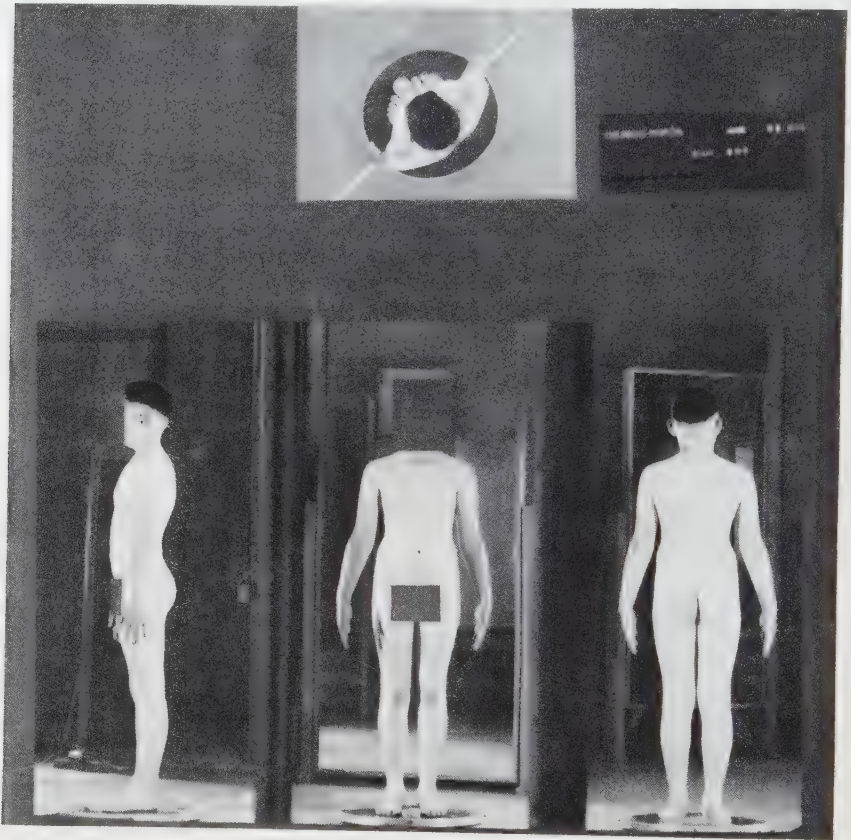


Fig. 2 "A Photo-Metric Picture."

0.1%. This calibration is alike in all Photo-Metric installations, so that slides made from films exposed at one unit can be measured on the projection screen of any other unit.

The manufacturer also has an experimental projector which enables the user to trace the body outline on a smaller scale, and the present senior author independently made a cruder

one from a photographic enlarger. Such equipment makes it possible to superimpose tracings of an individual before and after any somatic changes have occurred. From the negatives, the enlarger could be used nearly as easily to make double exposures on enlarging paper for the same purpose.

The central ray of the Photo-Metric camera lens is 101 cm above the base of the fixed pedestal, or at the level of the thorax or abdomen in most adults. This position is higher than the level of 81 cm used by Tanner and Weiner ('49). For the three full-length views, such a high position is advantageous in that it reduces distortion of the head and face. A lower lens would be somewhat more satisfactory in photographing the lower extremities, but in the front view would exaggerate the height from the floor of projecting structures such as the nose.

One shortcoming of most body build photographs is the distortion arising from an unduly short distance from camera to subject. Near the focal plane, the apparent breadths of broad and rounded parts of the body are then too narrow, and regions much closer to the camera than the focal plane are inordinately enlarged (Gavan, Washburn and Lewis, '52). To minimize such optical sources of error, Tanner and Weiner ('49) recommended that the camera be about 10 m (32.8 feet) from the pedestal. But most research organizations have too little space to permit such separation except in inconvenient locations such as hallways.

In the Photo-Metric system, however, the use of mirrors permits a lens-object distance nearly this great, even though the camera room itself (without the projection system) is only 5 m square. For the three full-length views, the lens-object distances are: Front, 9.26 m; Side, 9.17 m; Rear, 9.25 m.

In considering the usefulness of the Photo-Metric system for anthropological purposes, its limitations are as important as its assets. One such drawback is the use of the overhead view for photogrammetry. In this view, the pedestal and feet are much further from the lens than is the head. The focal plane lies about 68 cm above the pedestal. The photographic

diameter of the circular pedestal is 6.4% smaller than the true diameter, and the horizontal photographic dimensions of the head of a tall man are some 10% too large. The correction of this distortion might be accomplished with special rulers suitable for various horizontal planes parallel with the focal plane.

But linear distortion of the overhead view does not prevent its use for the measurement of *angles* defined by visible anatomical landmarks, particularly in the shoulder region. Before the individual is photographed, these sites should be made visible on the skin with gummed paper ring reinforcements or markings with a skin pencil. Such angular measurements have been made from all 4 Photo-Metric views by Blesh, Meyers and Kiphuth ('54). These authors carried out postural studies of over 2,000 undergraduates at Yale.

Another limitation of the Photo-Metric camera unit is the narrowness of its mirrors. If images of the entire body are desired, the individual must stand with hands close to the thighs. Surveys of seating or working positions for later photogrammetry would be impracticable.

The lighting, too, is relatively fixed, and so are the aperture of the lens and the shutter speed. The 4 electronic flash units produce negatives with very flat contrast, so that surface details such as muscles or bony landmarks are poorly defined. It is possible to improve the contrast of the negatives by makeshift adjustments such as blocking some of the flash units or introducing extra floodlights, but we have yet to see prints from Photo-Metric negatives which even remotely approach the quality achieved, for example, by Tanner ('55) in photographing adolescents with more conventional equipment.

A distinctive feature of the Photo-Metric unit is that the cameraman stands only about 2 m from the subject. From his position by the camera, the photographer can see the 4 mirror images, make minor adjustments in the pose, and then take the picture. He can directly see the left profile, but variations in the pose of the right arm are less readily corrected. Our tests indicate that the breadth of the right elbow is therefore

more variable than the left in successive slides of the same individual. If a poser is situated about 2 m to the right of the subject, this and other sources of posing error can be better controlled.

Our statistical studies of Photo-Metric data indicate that means and variances of measurements of the living should not be directly compared or combined with those of Photo-Metric series, but rather, living should be compared with living, and Photo-Metric with Photo-Metric.

When the habitual posture of a person considerably changes, photogrammetry portrays these alterations less accurately than conventional measurements of the living. The chief source of unreliability of Photo-Metric measurements is the anteroposterior sway of the body, so that transverse measurements of the head, neck or upper thorax are relatively unsatisfactory: whereas anteroposterior measurements are more precise and reproducible.

The Photo-Metric unit is available from the manufacturer on a rental basis. It is far too costly to be a part of a modest anthropometric laboratory, where no more than a few hundred body build photographs would ever be made in a year.

But where thousands of individuals are to be photographed, the cost per person becomes far more reasonable. At West Point and Yale, entire classes of students are photographed. Mass surveys of the armed forces might also be practicable. In such major enterprises, a well-organized team could probably photograph 1,000 subjects in a week.

Since the components of the Photo-Metric unit are essentially immobile, it is not practicable for anthropometric surveys where the measurers move about with portable equipment.

Where physical normality and excellent posing are characteristic of a human series, photogrammetry rivals the best that can be done in the living, and eliminates the awkwardness or other technical difficulties in many body measurements. But where a physically abnormal group is under considera-

tion, or where posing is unsatisfactory, the best procedure is to make caliper measurements of every individual, and to preserve body build photographs as valuable qualitative records.

ACKNOWLEDGMENTS

Mr. Theodore Yonkler, President of the Photo-Metric Corporation, helped considerably in technical aspects of this study. Mrs. Sophie Dobzhansky Coe performed the measurements of the Photo-Metric slides.

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A BLOOD TYPING OF HUMAN SKULL FRAGMENTS FROM THE PLEISTOCENE¹

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The Midland Skull, found in 1953 in western Texas, is possibly the oldest dated specimen of man yet discovered in the New World. Wendorf, Krieger and Albritton in their report ('55) on the find, assign it to a period definitely earlier than the occupation of that area by Folsom Man. At Lubbock, Texas, 150 miles to the north of Midland, the Folsom level has been established by radiocarbon dating as approximately 10,000 years old. Although a dating of Midland material from the level containing the human skeleton was dated as 7100 ± 1000 years old, the paucity of the sample has left the latter date open to question, especially since Midland human materials were found beneath a Folsom level.

From their analysis of all relevant data, Wendorf and his colleagues conclude that Midland Man lived prior to the last advance of the Wisconsin Glaciation. If so, probably he substantially preceded all other human remains in this hemisphere.

In June, 1955, Dr. Fred Wendorf supplied to the authors 20-odd fragments of Midland Man bones for blood grouping. Tests, however, were postponed until early February of 1956, which interval gave the authors an opportunity to complete, to their satisfaction, improvements and standardizations of techniques aimed at insuring more reliable results.

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Procedures were based on the work of Candela ('36, '37, '39, '40), Boyd ('34, '37, '39), and Matson ('34, '36), who, among others, successfully determined the blood types of bone, mummy tissue, and body fluids by means of the absorption (inhibition) of agglutinins. However, there has existed no hitherto practicable method of distinguishing the presence of the O antigen from an absence of A and B. Such absence of antigen might be occasioned by various agents, such as chemical action, leaching, or deterioration due to extreme antiquity. The solution of problems relating to the typing of old populations, i.e. the American Indian, which exhibit a high frequency of the O blood type, has been especially handicapped as a consequence.

Since the announcement of Boyd and Reguera ('49), and Boyd and Shapleigh ('54) of the lectins in *Ulex europaeus* seeds this laboratory has been exploring the possibilities of their use in absorption tests. While *Ulex* extracts have been quickly adopted for determinations of the Secretor factor in saliva, they have not been used, to the knowledge of the authors, for bone testing outside of this laboratory. Techniques involving the use of anti-O lectins of *Ulex* were accordingly, explored.

The use of absorbed cattle sera (beef anti-H) was also attempted, but because of its wide latitude of anti-H reaction, was found to be inconclusive and much inferior to *Ulex* extract.

Secondly, test procedures were assessed for accuracy by employing bone material of known A, B, AB, and O blood types. Autopsy material aged under controlled conditions, some specimens for a year, some for several, were used in establishing the reliability of testing procedures. Bone samples from 16th and 17th century Philippine cave sites, from the collection of the University of Michigan Museum of Anthropology, were also tested and clear reactions were obtained comparable to those given by known type bone.

Thirdly, standardized and equalized stock anti-A and anti-B sera were prepared, as well as *Ulex* extracts, and sealed and frozen in amounts suitable for individual tests.

The absorption test, as described by Candela ('37, '39) and Boyd ('37, '39), was used. This test involves the introduction of pulverized tissue or bone sample into antisera of known and identical titer, which is allowed to stand over a period of 24–48 hours. Any blood group antigen present in the sample will, as a consequence of specific antigen-antibody reaction, lower the titer of its appropriate antibody agglutinins, or even remove them altogether. Known erythrocytes, subsequently added to the centrifuged, clear supernatant antisera, act as indicators to reveal the presence or absence of agglutinins, and, accordingly, the corresponding antigen in the original sample.

All three antisera (anti-A, anti-B, and anti-H) were employed at three different titers each, namely, 32, 64, and 132. Titer in antisera is determined by means of progressively doubled dilutions with physiological saline solution, thus: 1:1, 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, 1:132. Titer indicates the highest dilution (weakest solution) capable of still yielding an observable agglutination reaction with appropriate known red cells. A serum with a titer of 32 would, accordingly, be twice as strong as one of 16.

The three titers used were not chosen arbitrarily. A preliminary test-run using anti-A, anti-B, and anti-O antisera at a titer of 16 showed all three tubes cleared of agglutinins by non-specific absorption. Therefore the antisera were of necessity used at higher titer in order to demonstrate differential absorption.

Four of the largest bone fragments, identified as portions of the skull, provided sufficient material for testing. These were finely ground together in a mortar and carefully mixed to insure uniform samples.

Anti-A and anti-B sera were employed in the dilutions as specified. Anti-O was prepared from *Ulex europaeus* in stronger concentration than that employed on saliva in the Secretor

test. Preparation consisted of the following: 25 gm of seed were finely ground in 500 cm³ of physiological saline in a Waring blender. The mixture was then alternately frozen and thawed, and stirred for 24 hours under refrigeration in order to obtain maximum extraction. The extract was cleared by prolonged centrifugation, methiolate added to a 1:5000 concentration as preservative, and the solution frozen in vials. Extract so prepared will exhibit sufficient concentration to tolerate dilution even when used at the high titer required in the following tests.

RESULTS

Readings of agglutination were taken at the end of a 30-minute interval, and again at the hour. Readings were as follows:

	32 TITER	64 TITER	132 TITER
<i>30 minutes:</i>			
Anti-A serum	—	—	±
Anti-B serum	—	+	+++
Anti-O serum	—	±	++
<i>One hour:</i>			
Anti-A serum	—	—	+
Anti-B serum	±	++	++++
Anti-O serum	—	++	+++

It may be noted that non-specific reduction in titer removed almost all agglutinins of the 32 titer antisera. In observing the clear differentiation in the removal of anti-A agglutinin in the 64 and 132 titer tubes, in contrast to the remaining anti-B and anti-O agglutinins, the authors felt justified in assuming a tentative type A for the specimen submitted.

However, two further questions presented themselves: (1) could non-specific absorption conceivably be greater in the anti-A antiserum than anti-B or anti-O, and (2) could the effect of soil contamination influence the results of the typing?

In attempting to solve the first problem, a series of dilutions employing the same antisera used in the bone typing

were set up, and samples of kaolin and benzonite, a diatomaceous earth, were added in the same amounts as the ground bone previously tested. Kaolin proved to absorb non-specifically by approximately one tube, that is, sera of titers of 64 were lowered to titers of 32. Benzonite, however, effected a more profound non-specific absorption, titers of 64 being lowered to 4, a total of four tubes cleared of agglutinins.

Significantly, however, the three agglutinins were equally affected, with no different degrees of non-specific absorption observable. We conclude from this that non-specific absorption, while probably a function of particle size and composition, does not account for the differential absorption which was observed in the bone testing.

The second problem involved the testing of sand samples sent to the laboratory by Doctor Wendorf. These included samples from the 5 deposits of sand distinguishing the Scharbauer Site: white sand, which formed the firm floor of the blowout in which the human bones were found; the gray calcareous sand constituting the matrix in which the remains were embedded; the red Judkins sand overlying the gray, and exposed along the bottoms and sides of the blowout; the tan sand of the Monahans formation; and the superficial loose sand.

Sand samples were added in equal amounts to serial dilutions of the standard antisera; results again showed no differential absorption between anti-A, anti-B, and anti-O antisera, although non-specific absorption lowered all titers approximately two tubes. We conclude from this that the nature of the materials surrounding the human bone, while exhibiting some non-specific absorption, do not account for the A reaction observed.

A bone found in the same deposit with the human remains, and identified as that of a rabbit, did not cause a differential reaction when the same techniques used in typing the skull were employed. This test offered further evidence that the A type antigens were not intrusive from the sand, nor mixed with other animal remains. That the specimen was indeed

human was indicated beyond doubt by the use of anti-human immune serum over which was layered an extract of the specimen. A distinct precipitin reaction was thus obtained comparing closely to the human control, in contrast to controls of dilute cow and buffalo sera.

Attempts to type the Midland Man fossil by means of a saline extract of ground bone in order to avoid the problem of non-specific absorption proved futile, however, extracts being too weak in antigenic strength to effect observable absorption. In the event of a larger sample, which would permit extraction and concentration by lyophilization, the authors feel that such a procedure might be utilized.

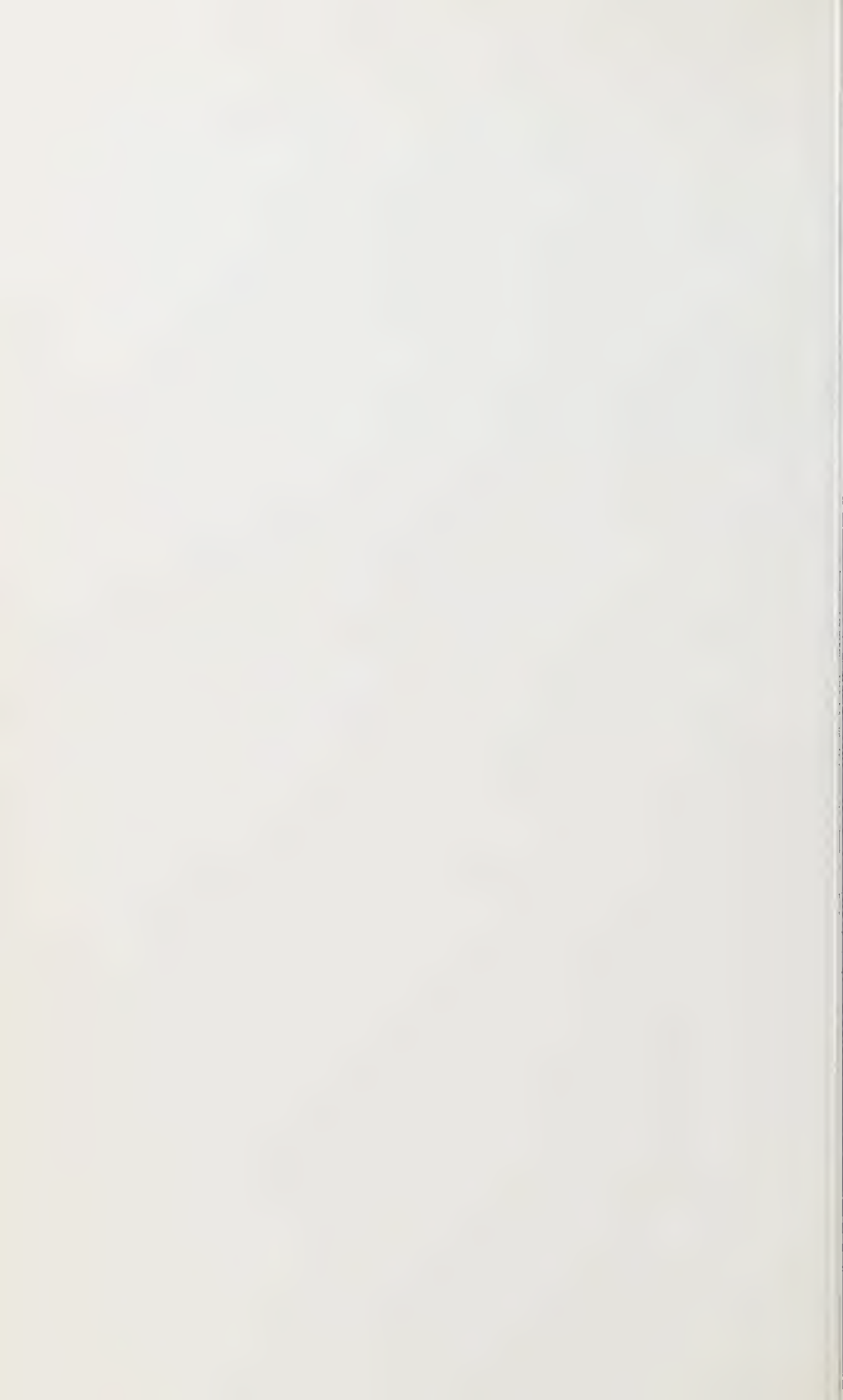
While the absorption reaction on anti-A serum reported here can be taken as presumptive evidence of A antigens, it is nevertheless important to establish the presence of complex organic material in the bone sample. In the report by Wendorf et al. ('55) on the Midland Discovery, Worman and Waskins (table 7) state that the organic content of the bone to be close to 1%, suggesting the presence of sufficient organic material to make testing for antigen residues entirely feasible. In addition to this, we undertook to test the bone sample for the presence of bound amino acids, since Abelson ('54) has shown that ancient bone, some going back to the Devonian, can be made to yield amino acids.

Acid hydrolysis of a small quantity (0.5 cm^3) of washed bone released appreciable amounts of amino acids (aspartic acid, glutamic acid, glycine, alanine, valine, and leucine) as revealed by dimensional paper chromatography. Thus complex organic compounds are shown to be still present in the sample.

In conclusion, the Midland Man find is very probably type A. As tests were performed to ascertain that the sample is human and does contain complex organic material, as well as eliminating the possibility of differential non-specific absorption or contamination from soil or associated fauna, the authors feel that the blood typing is as reliable as can be achieved by known methods.

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THE HENSHAW BLOOD FACTOR IN NEW YORK CITY NEGROES.

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The Henshaw blood factor, discovered by Ikin and Mourant ('51), occurs predominantly among Negroes and is genetically associated with the MNS factors. Mourant, as visiting professor at Columbia University in 1953, initiated study on the serology and genetics of the factor among Negroes of New York City.

One thousand blood samples, collected from Negro donors at certain blood banks in New York, were tested for the Henshaw factor. (The anti-Henshaw serum was prepared at the Lister Institute, London, by immunizing rabbits with suitable human red cells.) Those positive for Henshaw were then tested for ABO Group, MN, and S.

Of the 1000 bloods tested, 32, or 3.2%, were positive for the Henshaw factor. The distribution of the ABO types for these 32 bloods is similar to the incidence among the general New York City Negroes found by Miller, Rosenfield and Vogel ('51), as shown in table 1. This similarity is compatible with the assumption that the present sample is drawn from the same general population as was the Miller, Rosenfield and Vogel study. It further indicates that there is no obvious association between the Henshaw factor and the ABO Groups. The distribution of the 6 MNS types for the Henshaw-positive bloods, however, contrasts markedly with the general New York City Negro population. The Henshaw positives show greater association with the N and S genes than the general population, the NS phenotype being almost 6 times as frequent among the Henshaw positives.

The Henshaw frequency and its MNS association reported here may be compared with recent findings in Africa. Mourant ('54) finds the frequency of the factor in Nigeria 2.1% and in the Gold Coast 4.3%. All Henshaw-positives tested in West Africa also had the N factor and all except one had the S factor (Chalmers, Ikin and Mourant, '53). Shapiro has found 6% of Bantu Negroes of South Africa Henshaw-

TABLE 1

Distribution of the six MNS phenotypes and the four ABO groups for the Henshaw-positive bloods and for unselected bloods among New York City Negroes

	HENSHAW-POSITIVE NYC NEGROES		UNSELECTED NYC NEGROES	
	(Present study)		(M. R. V. study) ¹	
	Number	Per cent	Number	Per cent
O	16	50.0	100	50.0
A	7	21.9	44	22.0
B	7	21.9	47	23.5
AB	2	6.2	9	4.5
Total	32	100.0	200	100.0
MS	2	6.2	40	6.9
Ms	1	3.1	100	17.2
MNS	9	28.1	96	16.6
MNs	3	9.4	192	33.1
NS	11	34.4	35	6.0
Ns	6	18.8	117	20.2
Total	32	100.0	580	100.0

¹ Per cent reprinted, with kind permission of the authors, from Miller, Rosenfield and Vogel ('51).

positive. Nijenhuis ('53) reports 10 Henshaw positives out of 70 Congo Negroes tested, 7 of them showing the M and S factors. Allison et al. ('54) have found 11 positives among 93 Negroes of the Iraqw tribe in Tanganyika, East Africa, with an approximately even distribution among the MNSs factors.

The similarity of the Henshaw frequency among Negroes of New York City and West African natives is to be expected

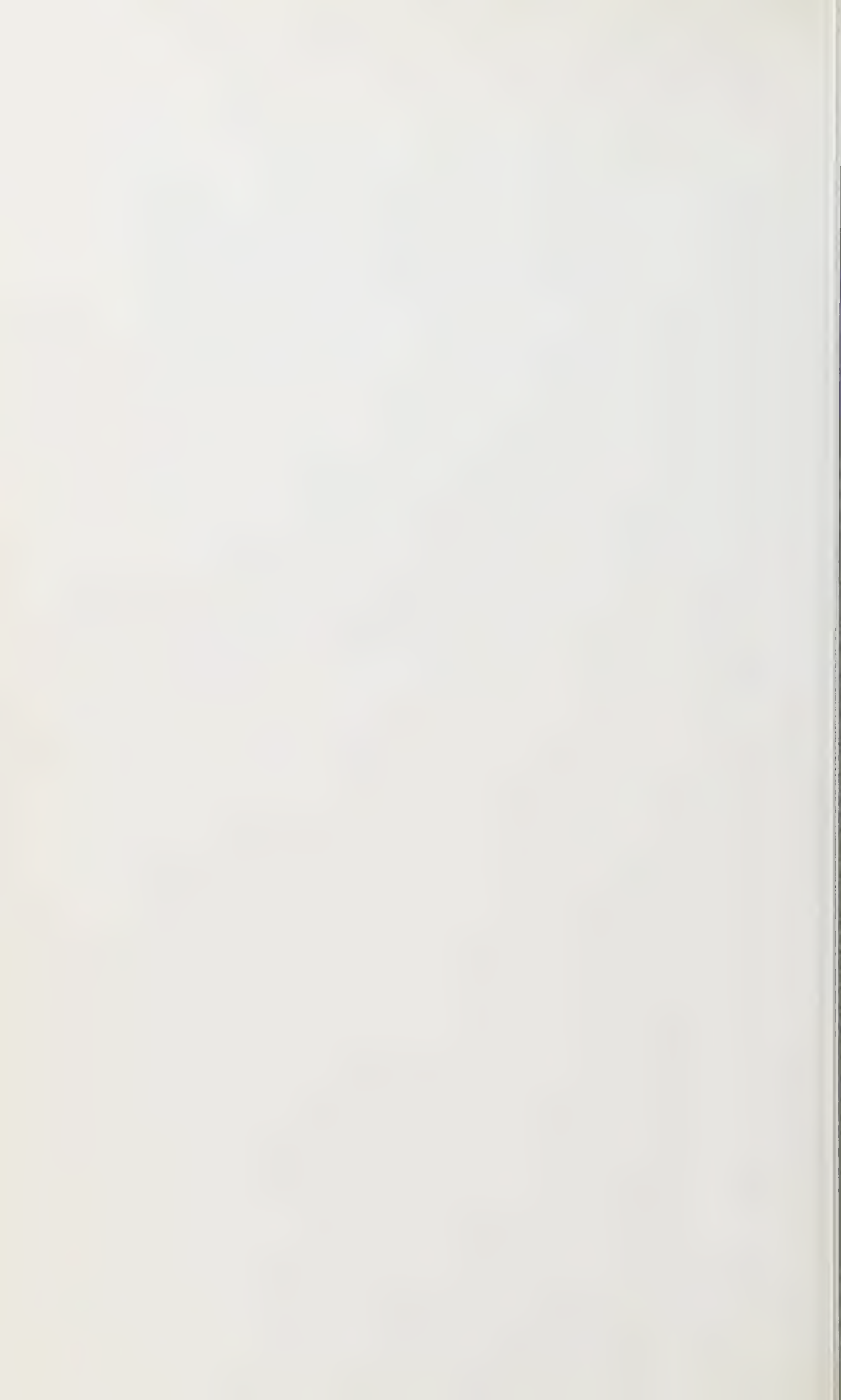
on the grounds that the great majority of Negroes imported to America came from the Western bulge of Africa. But the presence of the M and s genes with the Henshaw positives in the present study may reflect importations from the Central or even Eastern part of that continent. The figures presented here may, however, be primarily due to the sampling error inherent in a relatively small survey of a low incidence factor.

ACKNOWLEDGMENTS

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A COMPARISON OF HUMAN AND ANTHROPOID MESOSTERNA

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SEVEN FIGURES

INTRODUCTION

In a previous communication (Ashley, '56a) it has been shown that the great variability in shape of human mesosterna cannot be accounted for by sexual differences alone. Subsequently (Ashley, '56b), it was shown that the variability in the definitive shape of the bone was an expression of variability in its manner of ossification.

The present study investigates the problem as to whether or not the human sternum is more variable, and therefore less specialized, than the sternum of some of man's nearest relatives.

MATERIAL STUDIED

One hundred and ten Gorilla, 101 Chimpanzee, 15 Orangutan and 13 Gibbon sterna have been examined, and a proportion of them have been radiographed. Findings are compared with findings from a similar study of 1400 human sterna.

LITERATURE, FINDINGS AND DISCUSSION

Lubosch ('20) introduced the terms primatoid and hominid to distinguish narrow sterna from broad sterna (fig. 1). It is difficult for one to understand his use of the term primatoid in this connection, for there are many primates and one cannot say that they have much in common insofar as the form



Fig. 1 Illustrating the shape-characteristics of the primatoid and hominid sterna described by Lubosch. (Copied from original illustrations, Lubosch, '20.)

of the sternum is concerned. Radiographs of sterna of several different primates are shown in figure 2. The lack of uniformity in size and shape of these sterna is sufficiently apparent and obviates the necessity for further comment on this point.

Stieve and Hintzsche ('25) exposed certain inconsistencies in the work of Lubosch. Nevertheless, one must agree with the latter in regard to the use of the variability in the shape of the mesosternum as a means of classifying sterna.

Elsewhere (Ashley, '51, '53, '56) it has been shown that human mesosterna may be divided into three types, the characteristics of which are revealed in figure 3. Here the Type 1 sternum resembles Lubosch's primatoid sternum in respect to shape, but the author cannot support Lubosch's contention that this type of mesosternum frequently presents evidence of bilateral origin. On the contrary, it is almost invariably (about 90% of cases) derived from single midline centers.

The author's Type II sternum corresponds to Lubosch's mixed or hominid type of sternum at least insofar as general shape is concerned. Lubosch's additional criteria—shape of facets for costal cartilages, costal processes, lineae sternalis, etc.—are not relevant to the point at issue.

Wirth ('32) supported the views of his former teacher, Lubosch, but makes the following remarkable observation, "Wie schon Boenjamin an seinem kleinen Materiale feststellt, zählen die Orang-Brustbeine zweifellos ihren morphologischen

Merkmale nach noch zum 'primatoiden' Typ-wie alle übrigen Anthropoidensterna auch, ihrer breiten Form nach aber stehen sie dem 'homidien' Typ näher.' With reference to the statement italicized it is difficult to imagine how anyone could

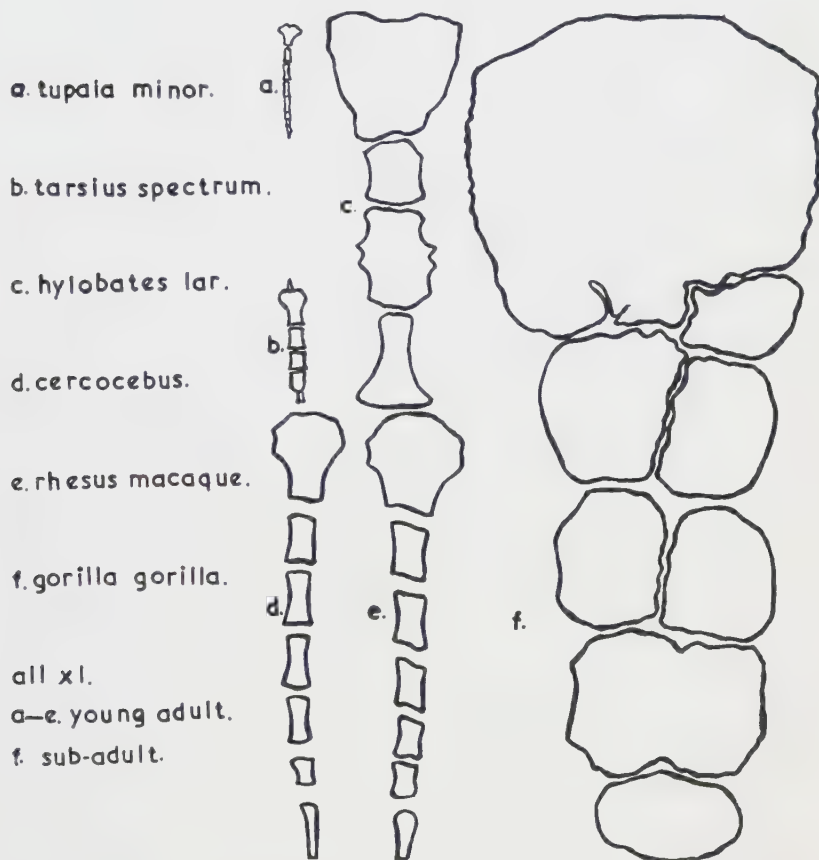


Fig. 2 Outline drawings of a series of primate sterna to illustrate the wide variability in shape and size. All $\times \frac{3}{4}$.

classify the excessively wide sternum of the Orang within Lubosch's primatoid group since the most *essential* "morphologisches Merkmal" of this group is surely the *narrowness* of the bone.

Gersch ('21) and Stadtmüller ('23) accepted the work of Lubosch, and the former showed undue haste in utilizing Lubosch's "sternal types" to classify certain negro races as "primatoid"—basing his opinion on examination of only 6 specimens. Stadtmüller's support, from study of only 14 specimens, was admittedly less emphatic. On the other hand Stieve and Hintzsche stated quite definitely that there were *no* distinctive racial characteristics in the sternum. Evidence from study of a much larger series of African sterna than had previously been reported on, completely refutes the generalization of Gersch and Stadtmüller. African sterna present the same variants of form, and in similar proportions, as do European sterna (Ashley, '56b).

TABLE 1

Comparison of average measurements of European and African human sterna

	MALE			FEMALE		
	European	African	% Diff.	European	African	% Diff.
	<i>Measurements in mm</i>					
M + B	156.9	142.6	9.1	138.7	127.1	8.4
S ₁	26.4	24.0	9.1	24.5	21.5	12.2
S ₃	33.7	30.9	8.3	30.5	26.8	12.1

M = manubrium. B = mesosternum. S₁, S₃ = width at waist of first and third segments of mesosternum.

However, African sterna differ from European sterna in two respects. (1) They are *absolutely* smaller in *all* dimensions than European sterna (see table 1) and in this respect would seem to be comparable to sterna of the Javanese (Boenjamin, '30). The East African sternum is about 9% shorter and 8-12% narrower than the European. (2) Without going into details, one can confirm a statement by Dwight (1890) that fusion of the individual bones of the mesosternum tends to occur a few years later in Africans than in Europeans.

With a few notable exceptions, the literature is lacking in adequate description of anthropoid sterna. Reference to single or a few specimens are made by Owen (1835, 1865, 1868), de Blainville (1840), Knox (1840), Humphry (1858),

Flower (1870), Lane (1885), Dwight (1890), Keith (1896), Duckworth ('15), Lubosch ('20), Stadtmüller ('23), Wilder ('26), Boenjamin ('30), and Raven ('50).

Schultz, more than any other anthropologist, has shown particular interest in the sternum and his investigations have involved study of large numbers of Chimpanzee, Orang-utan and Gibbon sterna. Of the Chimpanzee sternum he says ('40) "Nothing can as yet be stated in regard to the pre-natal and early infantile ossification of the sternum of Chimpanzee. It seems probable, however, that the sternal segments never have double ossification centers." He based this opinion on study of 78 specimens, of which a few were from infants and 29 from juveniles.

The present study of 101 Chimpanzee sterna included radiography of all but 8 specimens, the latter being incorporated in articulated skeletons. Of the 93 specimens radiographed, 10 were from infants, 19 from juveniles, 20 from sub-adults, 21 from young adults and 23 from old adults. Of these 93 sterna, 75 had been age-grouped by Ashton and Zuckerman according to the method they described in 1950. Findings from both radiographs and visual examinations are in *almost* complete agreement with Schultz's statement concerning the manner of ossification of the Chimpanzee sternum. In 99 of 101 specimens there was no indication that any segment of the mesosternum had arisen from more than one ossification center. Typical specimens are shown in figure 6. In the remaining two cases there were inconclusive indications that some of the mesosternal segments could have originated from paired bilateral centers.

There is a striking resemblance between the ossification pattern and definitive shape of the Chimpanzee mesosternum and the type of human mesosternum which I have called Type I (fig. 3). Such a sternum has the shape properties of Lubosch's primatoid group, but would be better classified as *panoid*.

With regard to the sternum of Orang-utan, Schultz, from study of 80 specimens, concludes ('41); "The sternum is

remarkably variable in regard to the number and arrangement of its bony elements . . . as a rule most centers of the corpus sterni remain separate until adulthood." He presents sketches of all these sterna, and from study of these sketches one is at a loss to understand how Schultz could reach these conclusions.

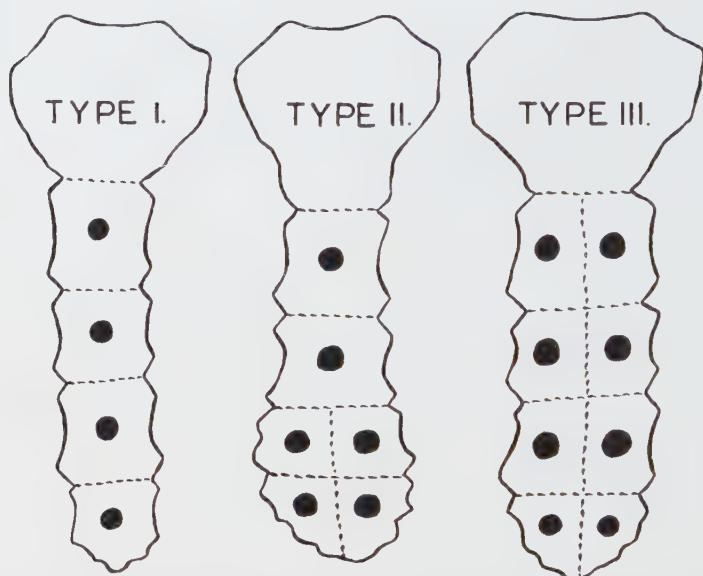


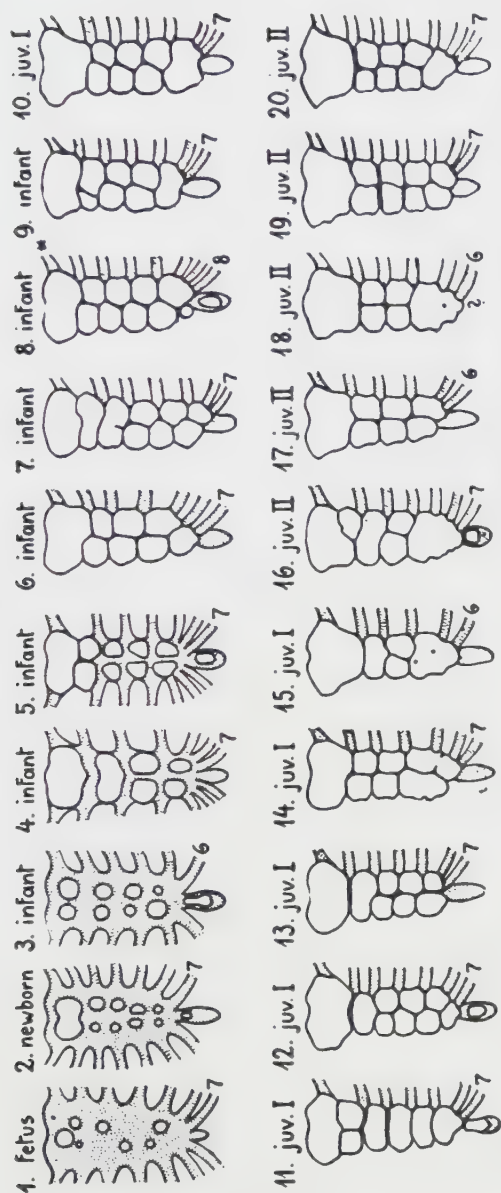
Fig. 3 Outline drawings illustrating the shape characteristics and ossification patterns of the three types of human mesosternum previously described (Ashley, '56).

Type I. Mesosternum narrow and with parallel sides.

Type II. Mesosternum narrow above, wide below.

Type III. Mesosternum wide and with parallel sides.

In assessing the ossification pattern of the mesosternum one should only consider those sterna in which the ossific centers have not lost their individuality through fusion with neighbouring centers. In the 8 *infant* sterna depicted by Schultz (see fig. 4) *all* show bilaterally paired centers in each of the mesosternal segments, and the only foetal specimen shows bilateral arrangement of the few centers which have made their appearance. In Schultz's original illustration it



(Reproduced by kind permission of the Carnegie Institution of Washington.)

Fig. 4 The ossification of the Orang-utan sternum (after Schultz, '41). See text for comment.

may be seen that as one passes through the juvenile to adult specimens one can easily observe diminution in the number of bones present through the fusion first of paired centers in each segment, and then of segment with segment until finally in the aged specimens the mesosternum is one piece. It is perfectly clear that the mesosternum of the Orang-utan normally ossifies from bilaterally paired centers in each segment, as de Blainville (1839), Parker (1868) and others have indicated. The author's series, though small, would support such a view. This arrangement is absolutely characteristic of the Type III human sternum described, a more appropriate name for which would be the "*pongoid*" type (see figs. 3, 4, 7).

It is interesting to record that the only case of thoracic ectopia cordis ever seen in a great ape occurred in an Orang-utan (de Garis, '34). This fact lends further support to the contention of Testut (1889) concerning the connection between *fissura sterni* and bilateral ossification (Ashley, '56b).

Classical descriptions of the human mesosternum reveal it to be narrow in its upper part and wider below, at about the level of the 5th costal cartilage. This corresponds to the Type II sternum (fig. 3), which the author has found in about 65% of 671 adult sterna, and to the "mixed" type described by Lubosch. This type can be justifiably designated as "*hominid*."

The mesosternum of Gibbons is variable, both in regard to its ossification and shape, in much the same way as is that of man (see Shultz, '44). However, it is considerably smaller, being probably never more than half the size of the average human bone.

There is little in the literature concerning the Gorilla sternum although isolated specimens have been described by numerous individuals. Most observers are agreed that it is very wide and that it usually presents evidence of bilateral origin (Owen, Wilder, Duckworth, Lubosch, Stadtmüller, Wirth).

Of the 110 Gorilla sterna examined by the author 64 specimens were radiographed. Of these, 12 were infant, 12 juvenile, 15 sub-adult, 15 young adult, and 10 old adult (Ashton and Zuckerman grading). From the radiographs it is apparent that the ossification pattern in the Gorilla mesosternum is almost as variable as in man, but there is a striking difference in the proportions of the various types. In Gorilla, one of the most common patterns is identical with the pattern most rarely found in man, that is the pattern called Type IV (Ashley, '56b), and which would obviously be better designated the *gorilloid* type (see fig. 7 upper row). Irrespective of ossification pattern, there is a tendency for all Gorilla

TABLE 2

The proportions of the four types of mesosterna in Man and the Great Apes

	TYPE I	TYPE II	TYPE III	TYPE IV
	%	%	%	%
Man				
European	24	64	12	1
African	20	72	8	1
Gorilla	8	2	46	44
Orang-utan	1	1	97	1
Chimpanzee	98	..	1	1
Gibbon	21	30	39	10

mesosterna to be wider above than below in association with the excessively wide manubrium of this ape. Nevertheless, insofar as ossification pattern alone is concerned it may be observed that the "pongoid" pattern is frequently seen in Gorilla (fig. 7 lower row), the "panoid" type occasionally, and the "hominid" type only very rarely.

From the material available it is estimated that the proportions of the 4 types of mesosterna in Man and the great apes are as shown in table 2.

In the great apes, especially in the Gibbon, it is sometimes extraordinarily difficult to determine where the morphological manubrium ends and the mesosternum begins. The classification of Gibbon sterna shown in table 2, is therefore only

tentative. These remarks apply in lesser degree to the other great apes also, and even in Man the sternal angle is occasionally opposite the third costal cartilage.

With regard to the findings reported above, the following question naturally arises. Which form of mesosternum indicates phylogenetic advancement — the narrow sternum which arises from single midline centers or the broad sternum which arises from paired lateral centers?

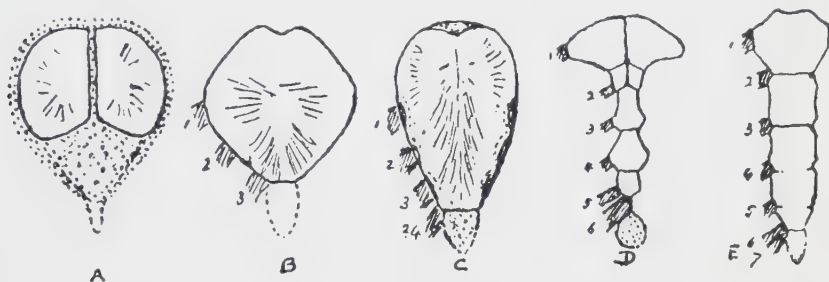
Certain observers obviously consider the narrow sternum of monkeys to be primitive and the wide sternum of Man, Orang-utan and Gorilla to be the consequence of phylogenetic advancement. For example, Tredgold (1897) states "A gradual, but marked reduction takes place in the total number of ribs as we rise in the animal scale" . . . etc. . . . conducing to "a gradual shortening of the thoracic cavity from below." He applies these rules to 10 genera of the order Primates and 6 orders of the class mammalia, arranging them in sequence to suit his own convenience. He illustrates his conception of the phylogenetic development of the sternum by his figure 2 in the communication quoted.

Keith ('02) holds a similar view and in 1948 stated "with the adaptation to the upright posture the thorax becomes flattened from back to front . . . the sternum also becomes wider and shorter"; and Schultz ('26) states "The phylogenetic reduction in the number of trunk segments in Orang has affected also the front of the thorax. The breast bones pictured illustrate their very marked variability which accompanies the phylogenetic shortening of the sternum . . . similar variations occur in Man, but are not as frequent as in Orang."

If these views represent a true conception, then they indicate a remarkable reversal of phylogenetic trend for, as Broom ('30) has shown, "The oldest known ossified sternum is found in the primitive Permian two-arched reptile *Younghina*. Here the sternum has two plates lying behind the coracoids . . .", and obviously he considers narrowing of the sternum to represent phylogenetic advancement as evidenced

by sketches of sterna of various species which he shows. These are reproduced in figure 5.

The narrowness of the Echina sternum shown in this series may have been a specialization in the development of the prototherian sternum so that *modern* representatives of this sub-class present a mesosternum less primitive in form than that of Man himself. It may also be remarked that even though the modern *Echidna* sternum is relatively narrow it still presents bilateral ossification in its upper part. Jones



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- A. Sternum of primitive Eosachian *Youngina*.
- B. Sternum of Anomodont *Lystrosaurus*.
- C. Sternum of Gorgonopsian *Lycenops*.
- D. Sternum of young *Echidna*.
- E. Sternum of Man.

Fig. 5 From this series of sterna (after Broom, '30) it would seem that phylogenetic advancement produces narrowing and lengthening of the sternum.

('29) stressed that a wide sternum, of bilateral origin, is essentially a primitive condition. He states, "There are more things than brachiating that can determine an animal's preserving or attaining the characters proper to the broad-chested type. . . . It is probably true to say that free fore-limb movements have preserved an originally primitive condition in Man and a certain otherwise ill-asserted set of mammals. . . ." It is felt that there is every justification for accepting this opinion.

CONCLUSIONS

Review of the literature combined with study of 1400 human and 239 anthropoid sterna, has led to the following conclusions:

1. *Sterna* of the Hominoidea may be divided into four types according to the ossification patterns and definitive shapes of the mesosterna.
2. The four types of mesosterna are described and illustrated.
3. Type I—the “panoid type” is characteristic of chimpanzee, but is found also in 20% of humans.
4. Type II—the “hominid type” is characteristic of man, being present in up to 70% of individuals.
5. Type III—the “pongoid type” is characteristic of orang-utan, but occurs frequently in gorilla and also in about 10% of humans.
6. Type IV—the “gorilloid type”—is commonly found only in gorilla.
7. The sternum of orang-utan is considered to be more primitive than that of the other Hominoids, whereas that of chimpanzee is considered to be most specialised.
8. The sterna of Man, gorilla, and gibbon, being subject to much variability, are held to be in a plastic stage of phylogenetic development.

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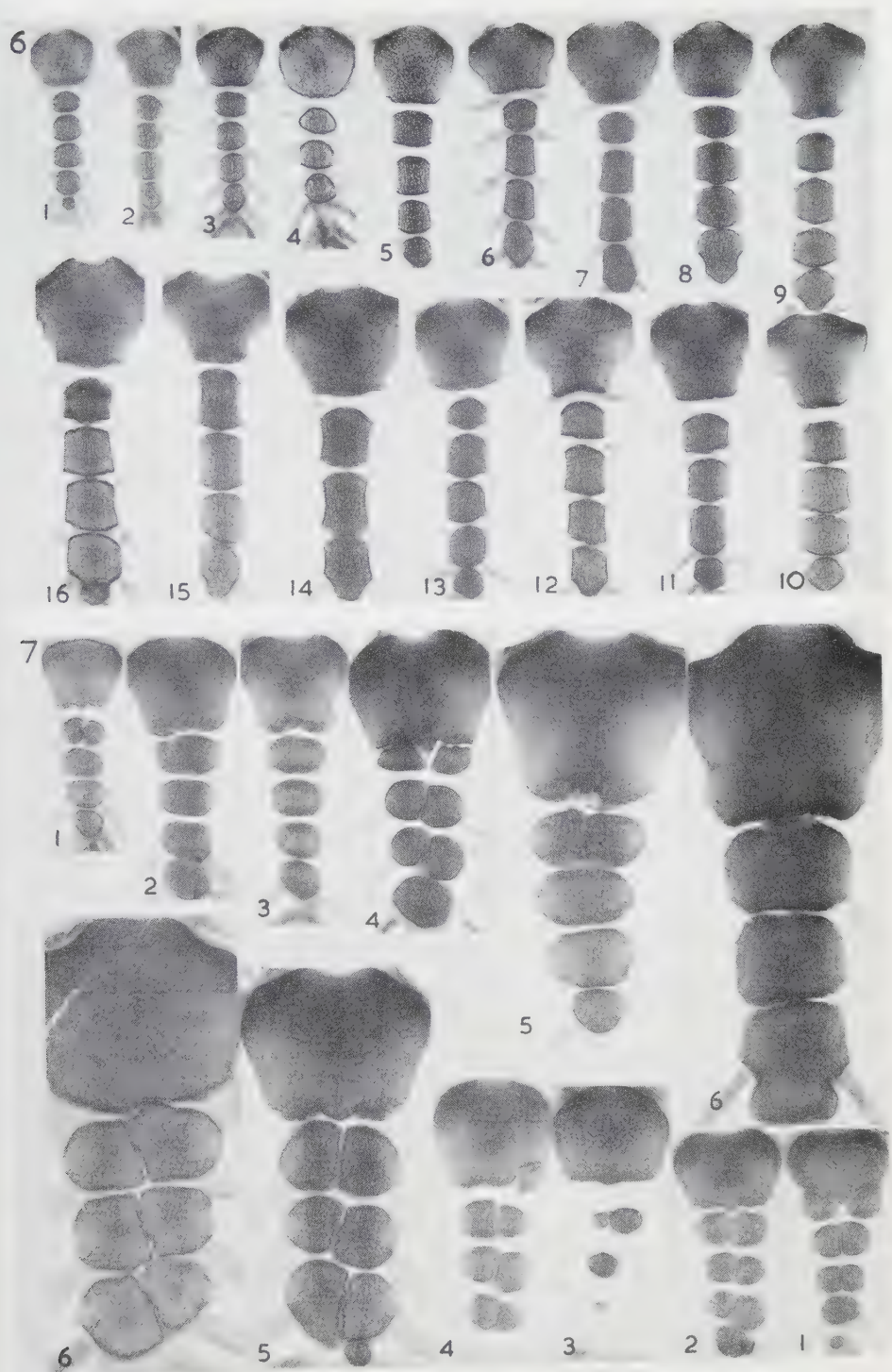
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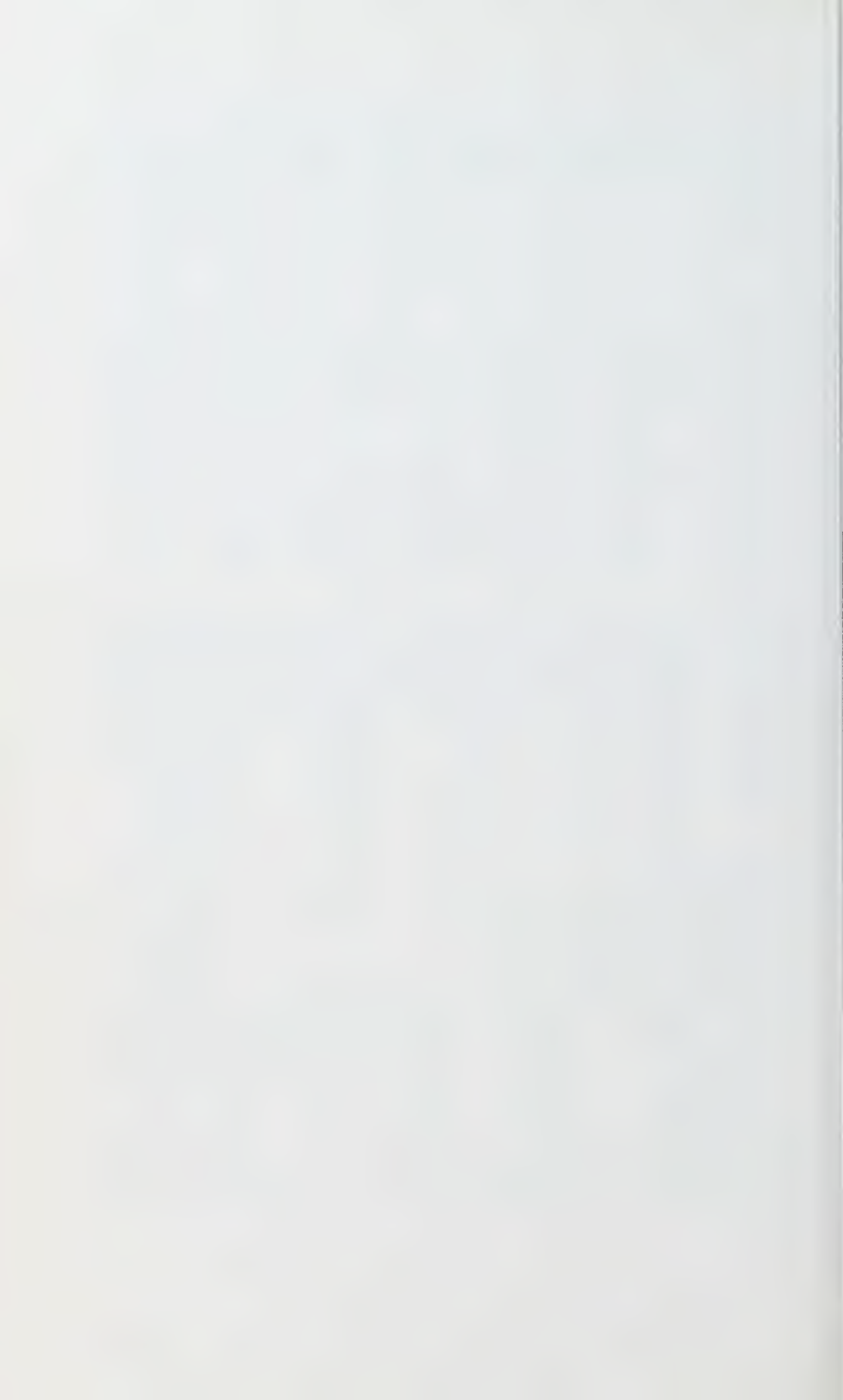
PLATE

PLATE 1

EXPLANATION OF FIGURES

- 6 Radiographs of chimpanzee sterna illustrating the characteristic narrow mesosternum with a single center for each segment. 1-3 infant; 4-8 juvenile; 9-16 sub-adult. All $\times \frac{1}{2}$.
- 7 Radiographs of Gorilla sterna illustrating the variability of shape and ossification pattern. Top row (Type IV — "gorilloid") 1-4 infant; 5 Juvenile; 6 young adult. Bottom row (Type III — "pongoid" variant) 1-4 infant; 5 juvenile; 6 sub-adult. All $\times \frac{1}{2}$.





THE FOSSIL HUMAN REMAINS FROM
THE PALEOLITHIC SITE OF SIDI
ABDERRAHMAN (MOROCCO) ^{1,2}

C. ARAMBOURG

Muséum National d'Histoire Naturelle, Paris

P. BIBERSON

Casablanca, Morocco

NINE FIGURES

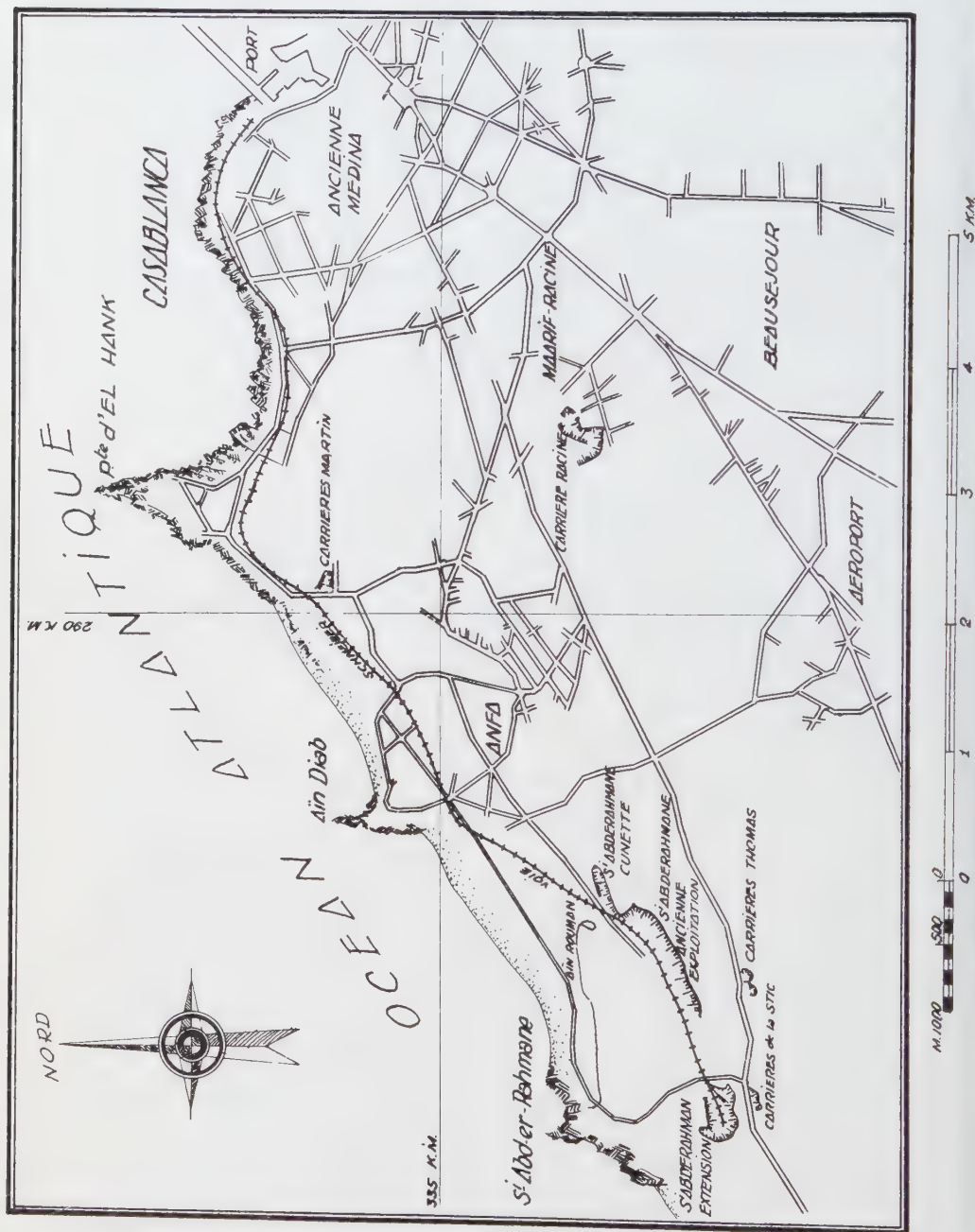
INTRODUCTION (P.B.)

In 1954 one of us (P.B.) discovered at the site of Sidi Abderrahman an incomplete human mandible associated with a Middle Acheulean industry and clearly dated to the beginning of the African Third Pluvial stage. Geologists and prehistorians interested in the Moroccan Pleistocene have known since 1941 the particular importance of the Schneider gravel pit at Sidi Abderrahman, southwest of Casablanca (fig. 1). In that year two prehistorians, R. Neuville and A. Ruhlmann ('41) published an account of paleontological and prehistoric discoveries giving to that pit the renown it has today.

Since then the exploitation of the pit has been continued. A new pit, under the aegis of the same company, was begun at Sidi Abderrahman — Extension; some comparable enterprises excavated in the S.T.I.C. pit and the Thomas pit in the immediate vicinity; finally, to facilitate the commercial excavation, a trench to permit locating a new working face ("cunette," in sand pit terminology), was opened in the northeast face of the old workings, along the whole length of a cut 1900 meters long.

¹ Translated from the French by F. Clark Howell.

² The cost of publication of this paper has been defrayed by a grant from the Wenner-Gren Foundation for Anthropological Research.



Parallel to the development of the pit, archeological and paleontological researches were continued. After the premature death of the earlier workers, new investigators undertook their work, so that today we possess a complete stratigraphic, paleontological and prehistoric series which permit one to control the observations of the earlier workers, and to arrive at new conclusions on the Pleistocene of the Atlantic coast of Morocco (Biberson, '55).

These new results have been fulfilled recently by the discovery of human remains which offer the possibility of identifying the makers of the Paleolithic industries collected. The present paper is an appraisal of present knowledge of this important site and the conclusions which may be drawn from it.

STRATIGRAPHY (P.B.)

Neuville and Ruhlmann's ('41) study was based primarily on two sections which have been protected by an "Arrete de Classement." An unfortunate circumstance, due to overlong exposure, led to the disappearance of Site B where their 'Clacto-Abbevillian' industry was discovered. The advance of the working face has permitted confirmation of the fact that the stratigraphy they described was especially localized, as Bourcart ('43) thought, and repeated soundings in the pit have confirmed these conclusions. This stratigraphy can not be generalized for the whole of Sidi Abderrahman and, obviously, even less so for the entire Pleistocene of this Atlantic coast.

Site A, on the other hand, was safeguarded and the northeast trench has cut through all the levels described by Neuville and Ruhlmann. Over a distance of 620 meters it has been possible to study a series of transverse sections 12 meters wide, and, due to the new working face, some 4×4 meter longitudinal sections.

The new observations confirm in great part those of the earlier workers; however, some subdivisions have been established, both in the marine and in the continental deposits

previously identified, in order to take into consideration various isolated horizons. The accompanying section (fig. 2) illustrates these observations in a schematic way. It uses the nomenclature of levels of Neuville and Ruhlmann ('41)

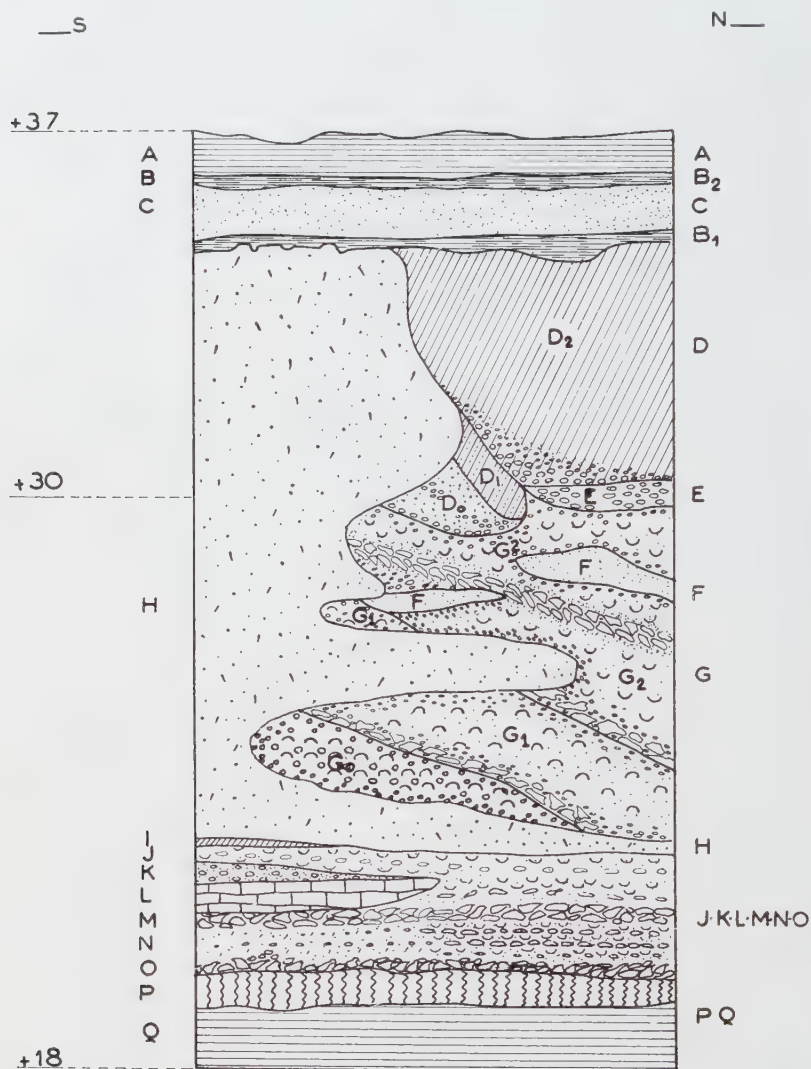


Fig. 2 Schematic section of the Sid Abderrahman "Cunette", with Neuville and Ruhlmann's nomenclature (left) and the revised nomenclature used in the text (right).

with the addition of supplementary designations when such subdivisions have been necessary.

There are two distinct marine cycles. The oldest basal formations rest on a pre-Pleistocene substratum of Cambrian quartzites and Cretaceous marls (symbols P-Q). The base complex, formed essentially of a conglomerate of more or less coarse elements and beach sand, is cut into this substratum; it comprises levels J-M-N-O, separated at Site B by Neuville and Ruhlmann ('41). There is no trace of levels I-K-L in the 620 meters of the trench.

Above, is the consolidated dune H (called the "Great Dune") which begins with beach sands and passes insensibly into blown sand. After the consolidation into sandstone of these strongly calcareous sands, this dune H was attacked as a cliff by a transgressive sea, belonging to a cycle more recent than the preceding formation. In this way, a tortuous littoral was created the coastline of which, hidden until recently under some fairly large landslides, has now been accurately revealed. Some karstic caves were developed in the mass of calcareous sandstone of the old consolidated dune. Certain of these, opening to the outside, were retreats for cave-dwelling animals and habitations of man.

When the transgressive sea reached these caves it disturbed the continental deposits which it encountered and threw them *pêle-mêle* with its own sediments at the bottom of the caves where they are found today under purely marine beds. This transgression must have reached an altitude of + 28-30 meters, since very characteristic beach formations are found at + 28 meters. The marine deposits were accumulated in places to a depth of 7 meters. In places too, they are constituted of a mass of marine shells forming very beautiful shell-marbles.

This molluscan fauna permits three superimposed horizons to be discerned: (1) horizon G_0 characterized by a gastropod, *Acanthina crassilabrum*, typical of the old warm Pleistocene, known today only in Chile and Peru; (2) horizon G_1 where the preceding warm fauna disappears, and a so-

called northern fauna with *Littorina littorea* increased; it is abundant today in the English Channel but does not seem, in the Atlantic, to pass south of the peninsula of Portugal; (3) horizon G₂ where the northern fauna is replaced by a new warm fauna with *Purpura haemastoma* which will very rapidly eliminate the old warm fauna of Chileo-Peruvian type which is on the way to extinction. With G₂ the marine series is ended.

Neuville and Ruhlmann ('41) believed they were able to isolate a level F, a dull brown sandstone containing sandworms. No one has found this bed in the form so described; on the other hand, lenses of sandstones, intrusive in various horizons of level G, are frequent. These are derived from marine sands, and redistributed by slope-wash. Undoubtedly, here is an example of dissolution pockets filled up by sand brought down by running waters. In other places these lenses are related to the base of the overlying continental levels and logically should be compared with them. Neuville and Ruhlmann's level E, which they said still contained numerous marine shells, is really the superficial part of Level G, weathered and partially redistributed by water action at the beginning of the subsequent regression.

The frankly continental formations consist of various horizons of level D. If subdivisions have seemed necessary, it is due to lithological differences, confirmed by the variety of prehistoric industries collected, although the paleontological evidence is not determinative. It is possible to isolate: (1) horizon D₀ consisting of yellowish-brown sandy sediments, slightly clayey at the base, which are in close relation with the sandy lenses F; (2) horizon D₁, which follows insensibly the lower horizon, composed of finer elements of clear yellow color becoming more and more clayey; (3) horizon D₂ very calcareous, of reddish color, and strongly brecciated in places. This latter horizon is the most developed and corresponds to Neuville and Ruhlmann's ('41) determination of a "red calcareous breccia." Its industry, as will be seen, is a great deal more evolved than that of the lower horizons, although

the mammalian fauna is scarcely different. Above is a calcareous crust (B_1) sometimes diffuse and penetrating the mass as concretionary nodules ("*en poupees*"), but perfectly bedded at the top.

On this crust a new dune (C) often rests. It is not greatly developed in the trench since it was in the way of the dead cliff, but is magnificently represented in the same sector, for example, at the S.T.I.C. pit and at the Thomas pit. This dune is sealed by a new crust, B_2 , which is perfectly fossilized. Finally, at the very top of the section, are found superficial formations (A) consisting most often of "red subaerial deposits," and characteristic of a new cycle.

Recent geological studies in the region of Casablanca have permitted identification of a series of post-Pliocene transgressions (Biberson, '55). The oldest, attributable to the Calabrian, seems to have had its shore line at an altitude approaching + 100 meters. It was followed by a first pluvial which left its traces in the form of rubified deposits. The maximum transgression of the second is not so clear; it seems to be located towards + 55-60 meters, where traces of it have been found. It is this cycle, and more precisely its regressive or final part to which the conglomerate at the base of Sidi Abderrahman belongs. Logically, it ought to be included in the Mediterranean Sicilian. The dune (H) is contemporary with the following so-called Romanian regression and with the second Pluvial *sensu lato*.

The following transgression which attacked the cliff of this petrified dune to reach a height of + 28-30 meters is accordingly the homologue of the Mediterranean Tyrrhenian I. The continental deposits surmounting this transgressive marine level belong to the Third Pluvial. Dune C is very likely contemporary with the post-Ouljian (Tyrrhenian II) regression. As for the "red subaerial deposits," geologists unanimously agree in dating them to the North African Fourth Pluvial (Grimaldian-Würmian).

The remains of Sidi Abderrahman man were collected in the sandstone F (D_0) at the base of the continental formations

infilling the dead cliff (Arambourg and Biberson, '55). This fossil is thus perfectly dated to the end of the maximum transgression of Tyrrhenian I, corresponding to the beginning of the North African Third Pluvial.

ARCHEOLOGY (P.B.)

If the stratigraphic and paleontological facts permit accurate relative dating of the fossil remains of Sidi Abderrahman man, the series of prehistoric tools which have been collected, either closely associated with this fossil or in the adjoining levels, testify perfectly to the industrial stage which this form had attained in the developmental succession of Moroccan prehistoric cultures. In practice, each of the geological levels isolated stratigraphically is also an archeological level. Naturally, the marine formations of Sidi Abderrahman, which are largely beach deposits, frequently provide a mixture of industries. In general, the physical condition of the pieces makes possible a classification; but, it is evident that this method can only be employed if numerous series are combined, permitting maximum elimination of chances of error. Besides, the abundance of implements in this sector proves that prehistoric man came onto the beach to obtain the primary material needed for manufacture of his tools. He left those which were badly made or those which were roughed out and of no immediate interest; therefore one is often struck by the coarseness shown by the assemblages collected. It would then seem advisable not to be misled by this archaic character and to reach judgments on the basis of the best pieces which only truly characterize a culture. Similarly, the technique of workmanship tends to be deceptive. The simplest, on a beach where there are large blocks, is the so-called *anvil technique* which permits large flakes to be obtained which could be retouched later as bifaces with a wood or bone billet. This technique is common everywhere in the whole African Paleolithic and does not serve to date the industry. These various considerations lead one to revise certain earlier determinations.

The conglomerate at the base of the Great Dune (H) contains some rolled tools: choppers and chopping/tools of the Pebble-culture type and some bifaces which are typologically attributable to the African Chellean. At the surface of the conglomerate, on the other hand, Neuville and Ruhlmann ('41) collected an unrolled industry the workmanship of which was essentially by the anvil technique, but where retouch by a stone hammerstone gave very regular pieces; some of the best made of these bear traces of a wood or bone billet. The first cleavers known in Morocco are to be noted also.

It appears that the essential characteristics of the Acheulean technique are present here. Thus, the "clacto-Abbevillian" of Neuville and Ruhlmann ('41) ought to be referred to the period of transition between the African Chellean and the Acheulean. The resemblances with the industries of stages 4-5 of Olduvai Gorge (Leakey, '51) are significant in this regard; it is for this reason that the author places it in the oldest Acheulean.

The base of the Tyrrhenian deposits of Sidi Abderrahman have furnished an abundant industry, notably in the "Cave of the Bears." Here is a still rather simple, but very characteristic Acheulean; the author has termed it Middle Acheulean I. The very special workmanship of very large flakes approaches that of the African Proto-Levallois (called "Victoria West"). The stone hammerstone is always most often employed, but there is increased retouch by wood or bone billet and cleavers are diversified. The top of the Tyrrhenian shows a refinement of this Middle Acheulean expressed in a tendency toward thinner bifaces.

The base of the continental deposits of the Third Pluvial, where the human fossil remains were collected, testifies to still further development (fig. 3). Although the stone hammerstone is still employed, there is general use of the wood or bone billet. Also, the bifaces become flatter, the edges more straight, and the forms more regular. With bifaces are associated unifacial tools on large flakes whose workmanship

testifies to the abandonment of the Proto-Levallois technique for the Tachenghit method, with smooth striking platform and nearly orthogonal flaking-angle. Cleavers become rarer when specialized tools like the side-scraper (still often bifacial) make their appearance. One finds here a Middle Acheulean still little refined, but which becomes perfected in the upper

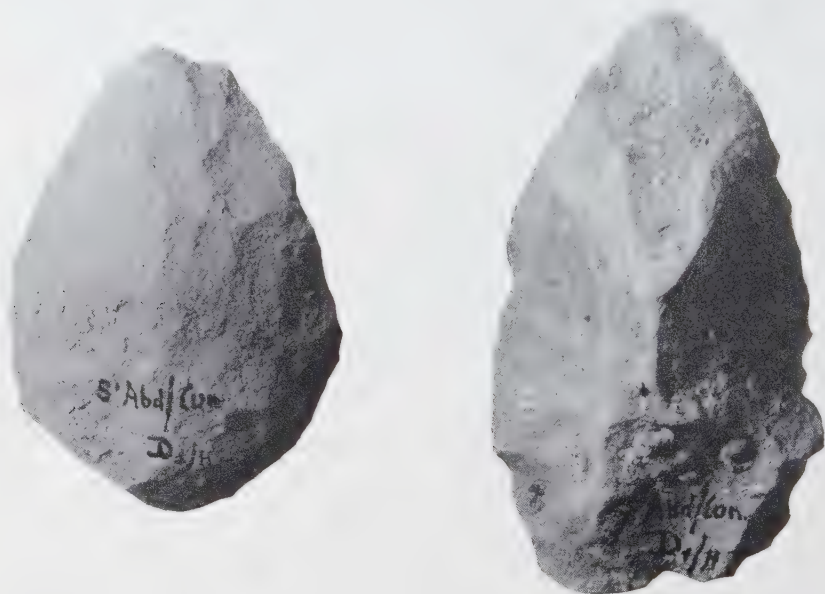


Fig. 3 Two bifaces of Middle Acheulean II (Littorina Cave, Level D₀ of the cave entrance in continuity with the sandy lens F containing the human fossil bones). ($\frac{1}{2}$ natural size.)

levels, to terminate in an evolved Acheulean in horizon D₂, the "red calcareous breccia" (fig. 4).

From this quick survey it is evident that Sidi Abderrahman man is perfectly dated, as much by his stratigraphic place at the base of the deposits of the North African Third Pluvial, as by his stone industry which, in the developmental series of the Moroccan Paleolithic, falls within the still rather rough Middle Acheulean, corresponding approximately to Chelles-Acheul stage 8 at Olduvai Gorge (Leakey, '51).

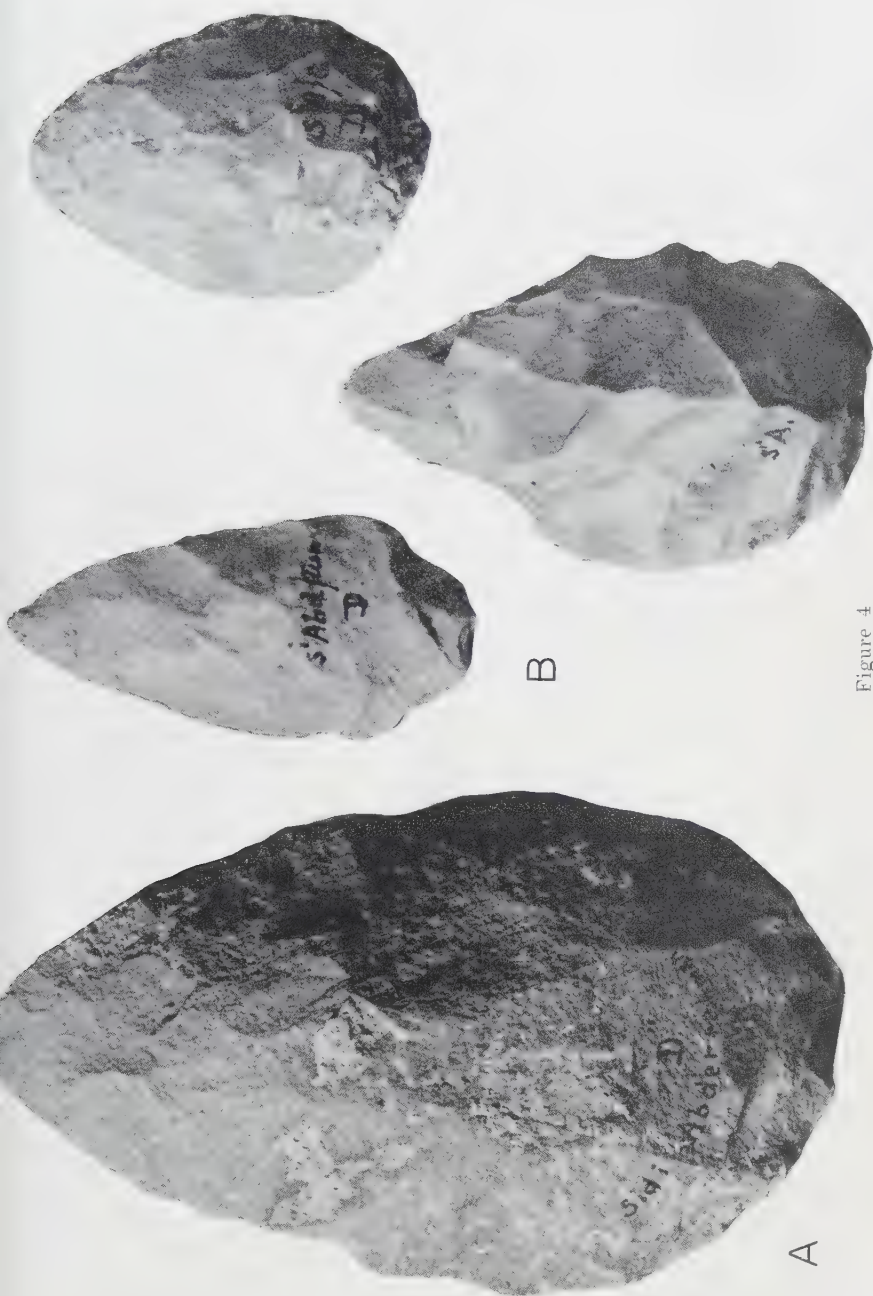


Figure 4

- A Large biface of the evolved Acheulean (Littorina Cave, Level D₂). ($\frac{1}{3}$ Natural size.)
B Three bifaces of the evolved Acheulean (Littorina Cave, Level D₂). ($\frac{1}{3}$ Natural size.)

THE HUMAN REMAINS (C.A.)

The various fragments of fossil human bone collected by P. Biberson in "Littorina Cave" permit reconstruction of a portion of mandible. This piece comprises two parts, which do not articulate unfortunately, but manifestly belong to the same individual. The main fragment forms the posterior part of the right body with the last three molars in place; this piece is broken just behind M_3 , of which the roots are apparent, and at the middle of the alveolus of P_4 ; the inferior border is intact. The second fragment is a part of the left postsymphysial region, with P_3 in place, and is broken just behind this tooth, as well as at the level of the mesial border of the alveolus of I_2 ; the latter tooth and the canine are missing.

Left postsymphysial fragment

This fragment is 20 mm long and 27 mm high (measured from the alveolar margin). Its inferior border is broken. In spite of this fragmentary state it is evident from the orientation of the external face of the bone with reference to the plane of wear of the premolar, as well as the slightly convex form of the buccal face of the root of this tooth, that the symphysial region sloped slightly backwards, following an angle of which the size order is comparable to that of the *Atlanthropus* II mandible. On the lingual surface, at the level of the canine alveolus, the bony surface below the alveolar border is flat, without a torus, and forms an angle with the buccal face comparable to that which is found in the same way in *Atlanthropus*; this disposition corresponds to an oblique, posteriorly sloping alveolar plane, such as is present in the pithecanthropines, including Heidelberg man.

The lateral incisor and canine are represented only by their alveoli. Their dimensions (in millimeters) are 5.5×9.2 and 8×10 , respectively. The buccal alveolar wall of the canine forms a slight ridge above the plane of the mandibular body.

The first premolar is single-rooted. The root length is a bit more than twice the bucco-lingual diameter at the level

of the neck; on its distal face there is a slight longitudinal depression. In *Sinanthropus*, as in *Atlanthropus* I, the root of P_1 is sometimes bifid, but with the two parts fused for the greater part of their length (cf. Weidenreich, '37, figs. 82, 85); however, certain specimens of *Sinanthropus* (*ibid.*, fig. 87) are single-rooted, with a single longitudinal depression on their distal and mesial margins, as in the Casablanca fossil.

The crown (fig. 5) is heavily worn and its height measures only 3.8 mm on the lingual face compared to 7.6 mm on the buccal face. Above the neck the buccal face forms a very slight projecting swelling, but without being a true cingulum.

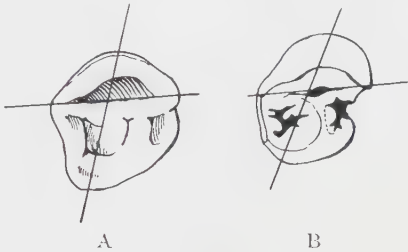


Figure 5

- A First left lower premolar of the Casablanca fossil man ($\times 2$), and
 B of *Sinanthropus* (after Weidenreich).

Nevertheless, at the distal and mesial borders, a trace of vertical cingular folds are clearly distinguishable, like those characteristic of the premolars of *Meganthropus*, *Sinanthropus* and *Atlanthropus*. It should be noted that the same folds are found attenuated in the Rabat fossil man.

In profile from behind, P_1 is notable in the obliquity and the curvature of the line which, at the neck, separates the crown from the root, so that the former slants much lower toward the buccal than the lingual. This is equally one of the characters presented by *Sinanthropus* (Weidenreich, '37, figs. 79, 82, 86, 87, 89) and which is found also in *Atlanthropus* I and II.

The contour of the worn surface of the P_1 crown is asymmetrical, the bucco-lingual axis being oblique to the mesio-distal axis. In spite of the wear on the crown, it is evident

that this tooth is formed of a main cusp compressed buccolingually which forms the whole external (buccal) wall of the tooth. A second, lower cusp is situated lingually and displaced slightly distally with reference to a perpendicular to the mesio-distal axis of the tooth. There are traces of a large posterior fovea and a more reduced anterior fovea. These various characters, very different from those which are present in the homologous premolars of *Homo sapiens* are, on the other hand, wholly comparable to those of *Sinanthropus* (cf. Weidenreich, '37, figs. 86, 87, 82, 84), *Meganthropus*, as well as *Atlantropus* I, II, III.

TABLE 1

Dimensions of the mandibular body of the Sidi Abderrahman fossil compared with some other fossil men

	SIDI ABDER- RAHMAN	SINANTHROPUS		ATLANTHROPUS		MAUER	H. SAPIENS
		G ₁	H ₁	II	I		
Height							
below M ₂	34.5	34	26	34	35	35	31.2-32.9 ¹
Thickness	17	19.3	15.4	16	19	20.4	12.7-13.8 ¹
Length of molar series	39.3	38.8	33 (alv.)	42	39	36.7	32.6-36.4

¹ After P. Topinard (1866); measured at the level of the mental foramen.

Right mandibular fragment

The total length of this fragment is 50 mm. The body is robust and its proportions recall those of comparable parts of the male *Sinanthropus* G₁ mandible (table 1).

The ventral border is regularly rounded and thick, but without forming a torus as clearly defined as those of the individuals already cited. The alveolar border is smooth, without a torus, and without tubercles or wrinkles, just as in *Atlantropus* I and II. The alveolar border and the ventral border are parallel, indicating as in *Sinanthropus* and *Atlantropus*, that the height of the mandibular body was constant as far as the symphysial region. It is known that in numerous living races this part undergoes a notable increase

in height as a result of the development of a projecting chin. On the lateral surface, the *prominentia lateralis* is not very prominent; similarly, on the lingual face, the bone is not much thickened below M_3 and the mylohyoid line is hardly marked in its anterior part.

The molars are very large, and although their crowns are heavily worn it is evident that these teeth were more brachydont than those of living races, resembling in this respect those of *Sinanthropus* or *Atlanthropus*. This character is seen well on M_3 where wear has hardly reached the cusps of the lingual border, and in which the crown height, at the level of the metaconid, does not attain half the length of the tooth; in living individuals by comparison this height sometimes notably exceeds the length (table 2).

TABLE 2

Index of brachydonty in the Sidi Abderrahman mandible, in the Ternifne II jaw, and in some recent human individuals

M_3	SIDI ABDERRAHMAN	ATLANTHROPUS II	LIVING MEN			
Metaconid height	5.5	6	5	6	6.2	5.6
Tooth length	12.3	13.1	10	10	10.6	10.7
Index	44.7	45.8	50	60	58.4	52.3

The separation of the crown and the root is very distinctly marked at the level of the neck where the crown bulges over slightly; there is the same rather rough trace there of a cingular ridge, particularly at the base of the buccal face of M_2 . The enamel of the buccal face is smooth, but presents some fine undulations, especially visible near the occlusal border.

The three molars form a series in which the third is reduced with reference to the first and second (as in *Homo sapiens*), but, where M_2 is larger than M_1 (fig. 6).

The crown of M_1 is subrectangular. Some of its dimensions are: length = 13 mm; protoconid-metaconid breadth = 11.6 mm; hypoconid-entoconid breadth = 11.2 mm. Although the cusps of this tooth are strongly worn and the fissures which delimit them on the occlusal surface partly effaced, the hori-

zontal contour of the crown presents some more or less marked indentations which correspond to their separation. On the buccal side, one such indentation marks the limit between the protoconid and the hypoconid; it corresponds to a deep vertical groove of the buccal face, marking the separation of the two cusps. The protoconid is deeply worn and a small island of dentine appears at the center where the enamel has been completely removed.

The metaconid and the entoconid are equally separated by an indentation of the occlusal face, but the vertical groove of the lingual face which separates the two cusps is less deep than that of the buccal face. The tip of the metaconid is less worn than that of the protoconid and is still discernible; on its mesial face it has an oblique wear facet which extends to the margin of the tooth.

The metaconid is 7 mm long, or 53.8% of the length of the tooth; the smaller protoconid is 5.8 mm long or 44.6% of the tooth length. The predominance of the metaconid—with the resulting asymmetry in the pattern of grooves on the occlusal face—is a primitive character constant in the australopithecines, and which is also to be observed in *Sinanthropus* (Weidenreich, '37, p. 78) and in *Pithecanthropus*.

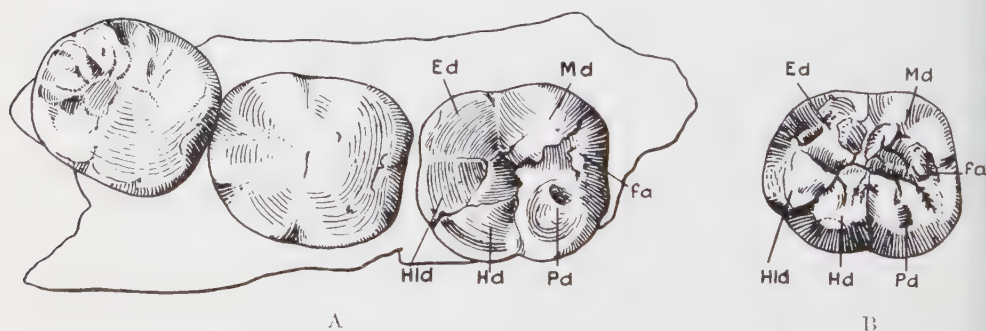


Figure 6

A—Molar series of the Casablanca fossil man ($\times 2$), and

B—an M_2 of *Sinanthropus* (after Weidenreich).

Ed, entoconid; Hd, hypoconid; Hld, hypoconulid; Md, metaconid; Pd, protoconid; fa, anterior fovea.

As a result of his structure, the metaconid is in contact with the hypoconid over a small distance on its disto-lingual border, and the pattern of the grooves has consequently the so-called dryopithecine Y arrangement.

The hypoconid is voluminous. On the lingual face of the crown the attenuated vertical groove which limits the hypoconulid is visible (a fracture of the crown masks this groove slightly, but it is nonetheless already discernible). The hypoconulid is separated from the entoconid on the occlusal surface by a slight groove which ends on the bucco-distal border of the crown at a very slight indentation, a trace of a groove which probably existed at this point on the vertical face of the crown. On the mesial part of the crown there is a slight groove which limits an anterior fovea between the protoconid and the metaconid like that in *Pithecanthropus* or *Sinanthropus*.

TABLE 3

Dimensions of the molar teeth of the Casablanca human fossil

	M ₁	M ₂	M ₃
	mm	mm	mm
Length	13	14.4	12.2
Max. breadth	11.6	11.4	11.2

The roots of this tooth are visible. They number two, and are broad, compressed disto-mesially, subparallel and deeply set in the mandibular body where they almost attain the center of the height of the bone. They each seem to have two paired pulp cavities.

The second molar is distinguished from the first by its more elongated (mesio-distally) form. The contour is elliptical. The deeply worn occlusal surface is almost smooth; there is merely a trace of the metaconid which forms a small eminence toward the bucco-mesial angle and which bears on its mesial face an oblique wear facet corresponding to the contact of the opposite maxillary molar.

The contour of the occlusal face presents some indentations which correspond to the grooves separating the cusps; these

grooves, 6 in number, correspond to the cusps of M_1 , but there is moreover an indication of a 6th cusp between the hypoconulid and the entoconid, in the buccal half of the crown. The corresponding grooves on the vertical faces of the tooth are very attenuated, except for that separating the protoconid from the hypoconid which ends abruptly towards the base above the previously noted vestige of a cingular ridge. This tooth has two roots, equally well separated and each bearing two pulp cavities.

The third molar is smaller than the preceding two and is somewhat less worn. The protoconid and the metaconid are the largest cusps. Since numerous secondary wrinkles cover the other cusps, their delimitation is difficult; nevertheless, the grooves of the vertical faces permit at least 5 cusps to be recognized; the presence of a 6th cusp is not certain.

There are two roots. The first, which corresponds to the first (= protoconid-metaconid) lobe, is compressed mesio-distally and has two pulp cavities. The second is simple, conical, with only one pulp cavity, and diverges from the anterior root by curving posteriorly.

The specimens examined here are distinguished essentially from those of *Homo sapiens* by their absolute dimensions, their massiveness and their macrodonty, as shown by the figures in table 1. Comparing the homologous dentitions of Neandertals (Patte, '55) their dimensions also separate them, but to a lesser degree. Thus, if one compares the figures in table 1 with those collected by Patte ('55) for various Neandertals it is evident that in the latter, at the level of the mental foramen (where the body is generally higher than at the level of M_2), the height in various specimens varies from 24–37 mm (mean = 30.3) and the thickness from 13–18 mm (mean = 15 mm). Similarly, the length of the molar series varies in the Neandertals from 33–39.5 mm (mean = 36.05 mm). Contrariwise, these various dimensions in the Sidi Abderrahman fossil are of the same order as those of *Pithecanthropus*, *Sinanthropus* G₁, and *Atlantropus* I and II.

Morphologically, the teeth of this fossil show, in spite of their advanced wear, the essential characteristics of the pithecanthropines: trace of a cingulum on M_2 , and distal and mesial cingular ridges on P_3 ; predominance on the molars of the protoconid over the metaconid, and dryopithecine disposition of the 5 main cusps; traces of a *tuberculum sextum* on M_2 .

Nevertheless, if the length of the molar series is almost the same as that of *Atlanthropus* I, *Sinanthropus* G_1 , or *Pithecanthropus*, the proportions of the teeth are somewhat different. Those of the Moroccan fossil are relatively more narrow; M_2 especially has a noticeably elliptical contour, whereas in the other fossils this tooth is subrectangular like M_1 , or even, broader than long in *Sinanthropus* G_1 . Finally, the third molar is proportionally more reduced than is that of *Pithecanthropus*, but recalls in this respect that of *Atlanthropus* I and II.

CONCLUSIONS (C.A.)

It appears evident that the mandibular fragment from Casablanca belongs to an early man more primitive than the Neandertals and still very close to the pithecanthropines; notably, *Atlanthropus* of Ternifine (Arambourg, '55), from which it is distinguished only by some characters which could be considered, judging from the three mandibles known of this fossil, as falling within the range of possible individual variation of this type.

Furthermore, it is important to affirm that the human remains, rigorously dated stratigraphically to the next to the last great marine regression contemporary with the Riss glaciation, furnish a second anthropological landmark in the history of African Middle Pleistocene men. The first was provided by the Ternifine fossils, of which the age is the beginning of the Middle Pleistocene, which corresponds approximately in the stratigraphic series of Sidi Abderraham, to the basal levels J-O, or to the base of level H.

It also seems that the fragment of "Rabat Man" ought to be attached to the same type. In fact a certain dental sim-

ilarity exists between these two fossils; in particular the development of a cingulum on the premolars and on M_1 , as well as the morphology of P_3 , of M_1 and M_3 (the latter, in the Rabat fossil having a *tuberculum sextum*), seems to be of the same order. The most notable differences between these two fossils lie in the weak height of the Rabat mandible, its great thickness, its almost vertical symphysis (on the buccal face), and the indication of a *trigonum mentale*. It should be noted, however, that this is a non-adult subject, with teeth scarcely worn and in which the last molar has just begun to emerge from its alveolus. In *Sinanthropus* some differences of the same order have been observed between adult mandibles and those of young individuals, although the symphysis of the later are more inclined than those of the Casablanca fossil; but, the presence of a *trigonum mentale* is also very well marked. Chronologically, the Rabat man belongs to a time almost contemporary with that of the Casablanca fossil, for it comes from levels of the "Great Dune," which after the most recent observations, can be attributed to a phase of post-Tyrrhenian regression, i.e., Third African Pluvial.

The association at Casablanca of a pithecanthropine and an evolved Acheulean industry confirms the idea, which the author has already expressed at various times, according to which each evolutionary stage of the human phylum corresponds to limited psychic possibilities which are expressed by the very nature of the industries accompanying the fossil human remains. It is known today, from the recent discoveries by Dart and his co-workers at Makapansgat that the Pebble-Culture is the work of the australopithecines; the discovery of *Atlanthropus* has shown that the pithecanthropines manufactured the first Acheulean bifaces. The Casablanca discoveries corroborate the earlier finds and prove that the "pithecanthropine" type is responsible for the bifacial industries in general, and that his existence extended over the greatest part of the Middle Pleistocene, up to and including the next to last pluvial. Finally, the Neandertals

are the workers of the Levalloiso-Mousterioid industries, and *Homo sapiens fossilis* those of the Upper Paleolithic. One cannot insist too much on this correspondence between the human forms and the successive industries, and on the generality of this fact throughout the Old World; and, also, on the fact that these industries succeed one another in a discontinuous fashion, gradually, without the most recent being directly derived by slow modifications, from those which immediately preceded them.

Each human industry is the psychic reflection of its makers; each corresponds to a mode of life and certain needs, in a word to a determined "vital standing." It is remarkable to note that the progressive complication of this "psychism" accompanies that of the cerebral mechanism, of which the quantitative and qualitative growth is characteristic of the human specialization. It is also remarkable that these phenomena have occurred gradually and discontinuously, so that one could almost employ the term "cerebralization quanta" to characterize them.

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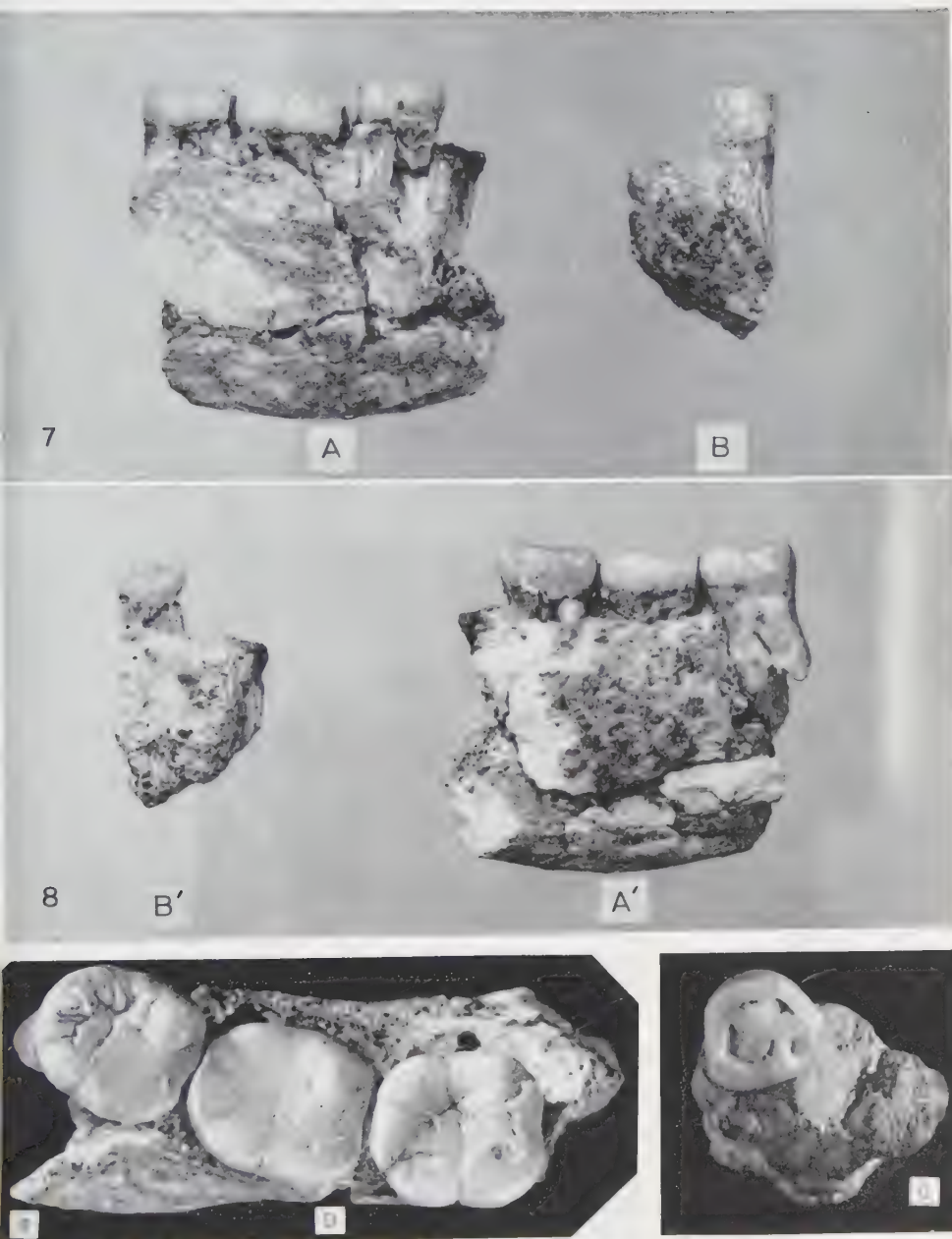
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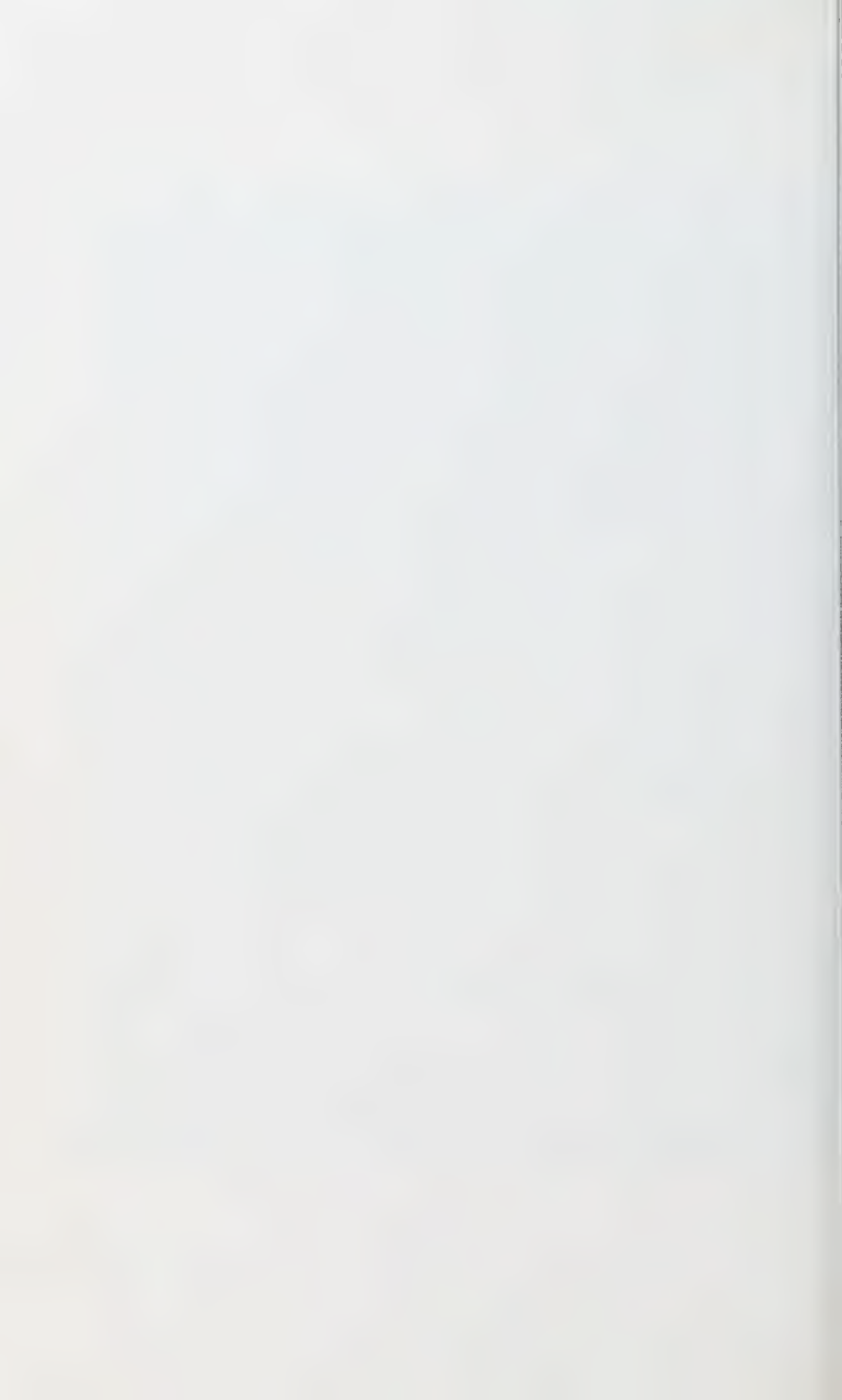
PLATE 1

EXPLANATION OF FIGURES

Mandibular fragments of the Casablanca fossil man.

- 7 A — Lateral view of right posterior fragment (natural size).
A' — Lingual view of right posterior fragment (natural size).
- 8 B — Lateral view of left postsymphysial fragment (natural size).
B' — Lingual view of left postsymphysial fragment (natural size).
C — Occlusal view of left P₁ ($\times 2$).
- 9 D — Occlusal view of molar series of right posterior fragment. ($\times 2$.)





ON THE FREQUENCY OF THE MISSING AND PEG-SHAPED MAXILLARY LATERAL INCISOR AMONG FINNISH STUDENTS

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TWO FIGURES

The study of the frequency of the reduction phenomena of the maxillary lateral incisor is an interesting object especially from the viewpoint of anthropology and racial studies. Regarding these fields, this subject has been dealt with in detail by Pedersen ('49) in his monography on the Eskimo dentition. The investigations by Schulz ('32) and Montagu ('40), with their extensive list of references, also deserve attention.

The only frequency study including partly Scandinavian material seems to have been published by Röse ('06). He studied the relationship of the reduction tendency of the maxillary lateral incisor, the missing incisor and the peg-shaped incisor to the cephalic index and found these two phenomena to be closely associated with each other. In one of the groups studied, consisting of 8618 girls, aged 10-14 years, the most dolicocephalic Swedish subjects (mean index = 79.6) had a reduction percentage of 8.4, and the most brachycephalic German subjects (mean index = 86.2) a reduction percentage of 3.1. In another group of dolicocephalic (78.5) Swedish soldiers, the reduction percentage was 5.9, and the most brachycephalic (85.4) German conscripts had a reduction percentage of 2.3.

As a self-evident conclusion Röse states: "The growth of the dental lamina is retarded more in the region of the front arch in dolicocephalic persons, whereas in brachycephalic

persons the posterior part of the lamina suffers most in its growth." According to this one would expect that, if the proliferative growth of the dental lamina in dolicocephalics really is hampered in the way Röse says, the percentage of missing lateral incisors would be greater in dolicocephalics than in brachycephalics.

The author calculated from Röse's figures percentages of missing lateral incisors only, leaving out the peg-shaped teeth. These figures show, that in the first group of girls the frequencies of missing laterals were 2.1 (S.E. = 0.79) for dolicocephalics and 2.0 (S.E. = 0.23) per cent for brachycephalics, and in the second group of soldiers 2.2 (S.E. = 0.38) and 1.4 (S.E. = 0.20) per cent, respectively. This would prove that there is no association between the absence of lateral incisors and the cephalic index. The seeming correlation presented by Röse is apparently due to the preponderance of peg-shaped laterals in the dolicocephalic groups.

There are some other authors who have presented high percentages for the peg-shaped lateral in literature; Thomssen ('55) 5.0 for Tristanites, Hrdlička ('21) 8.4 for Chinese males and 4.0 Chinese females. These forms have been called by different names — pyramidal, conical, peg-shaped, abnormal, degenerated or diminished in size, apparently depending on the subjective estimation of the author.

The whole question, however, would deserve a thorough-going investigation.

Kajava ('12) published an extensive study on the teeth of the Finnish Lapps, and stated on the basis of his material consisting of 180 skulls that he found no missing or peg-shaped lateral incisors. It is to be noted that in his material there were only 30 lateral incisors left in the upper jaw, and consequently, he had to base his conclusion mostly on the empty alveoli present.

Hjelmman ('28), in his monography of the dental morphology of the Finns, also based on crania, states that the frequency of the reduction phenomena of the lateral maxillary

incisor was 1.8% ; the number of upper lateral incisors present in the total of 336 crania was only 61.

Löfgren ('36) studied the frequency of missing and peg-shaped laterals in Finnish patients and prisoners, the material including 168 females and 577 males. Two females had one lateral missing, and two of them had a peg-shaped lateral incisor, and three lateral incisors were found missing in the male group.

Ekman ('38), while studying the eruption of the permanent teeth in Finnish children, specifically stated that in none of the year groups studied, consisting of 500 persons each between 10.5–14.5 years of age, was the eruption percentage of the upper lateral incisor = 100; in these children the percentage varied from 98 to 99%. No sex difference was found.

The present study gives information of the missing and peg-shaped maxillary lateral incisors in a group of 2218 Finnish freshmen students, who were included in a clinical dental survey in 1949, arranged by the Dental Health Committee of the National Union of Students in Finland and performed by the author ('55). This sample represents 93% of all freshmen students at that time enrolled in the University and in various colleges in Helsinki. Their age distribution, separately for both sexes, is given in figure 1.

At the examination, attention was paid only to the congenital absence of a tooth from the dental arch and to the presence of a clearly reductive peg-shaped tooth. It is generally considered that both of these phenomena are signs of reduction, and, as many authors claim, they may be determined by a common hereditary factor.

The results are presented graphically in figure 2, in which can be seen the sex distribution, missing and peg-shaped incisors separately and the distribution between the right and left halves of the maxilla. Different possibilities of variation regarding the form and degree of reduction add up to 9, when normal conditions also are included. The series has been so arranged that the tendency towards reduction increases downwards on the graph. At the top of the series

are the bilateral normal forms; then follow the unilateral reductive cases, first the degenerated teeth and then the missing ones. The 4 last rows represent all the bilateral reduction cases, the first two ones asymmetrical and the last two sym-

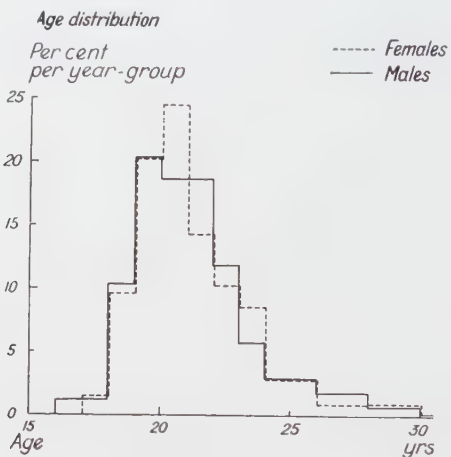


Fig. 1 Age distribution of the student material.



Fig. 2 Frequency distribution of combinations of various types of the reductive maxillary lateral incisor.

metrical possibilities. Both the peg-shaped and missing tooth can thus be present in 5 different combinations.

It should be noted that all the possible combinations were really encountered. Missing and peg-shapeness counted together were found in ca. 2% of the persons, both phenomena in about even numbers; the percentages were about equal as to the both halves of the maxilla and finally regarding both sexes. There is hardly any reason for going into more detailed divisions because of the small frequency figures in this sample. The results are in agreement with the previous information regarding the Finnish population, as can be seen from Ekman's figures mentioned above and also from Hjelman's results, although this last material was very small.

In the present material there were no signs of supernumerary lateral incisors, neither were any central incisors found missing. Three male students had supernumerary incisors present between the central incisors. One of them had two supernumeraries symmetrically located on both sides of the midline. The ratio between the missing and supernumerary teeth in the region of upper incisors was 54 to 4 according to the number of teeth and 41 to 3 according to the number of affected persons.

When evaluating the results, two things have to be considered, namely, the non-randomness of the sample and the fact that the examinations had to be carried through rather hurriedly and that the two surveyors did not at that time pay any special attention to the present problem. The results cannot therefore be considered generally representative.

Another source of error was found in the sample studied: in spite of the young age of the students many of them had prosthetically replaced upper lateral incisors, of which no anamnestic information could be obtained. This is a factor worth special attention in studies concerning adult populations. In this study, ca. 1.5% of the upper lateral incisors had to be excluded for this reason. The impossibility of ascertaining the past dental history of the persons as well as

the lack of roentgenological control is, of course, another considerable drawback in judging the present material.

The phenomena discussed here are interesting enough to warrant more thorough investigations on large samples and could perhaps best be carried out in connection with public dental service. Large and fairly random samples could then also be followed for a longer period at a time, which is important from the point of view of general dental development. This period would also be suitable for studies regarding the hereditary nature of the phenomena in question, as well as for checking the past dental history of the subjects.

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CONCURRENT FAT LOSS AND FAT GAIN

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TWO FIGURES

INTRODUCTION

While investigating the subcutaneous fat patterning of young adult males on a weight-reduction diet (Garn, '55; Garn and Brožek, '56), we observed that one of the measured fat thicknesses, namely the anterior leg fat, was notably thicker than that of older men even though the older men were fatter.

Subsequently, in studying fat patterning in the female we again encountered the tendency for this one fat thickness to be greater in young women than in their more mature and fatter elders (Garn, '56b).

As a result we decided to explore the subject further, gathering data on subjects over a wide age range (12.5 to 65 years), and from a single population sample. We also checked the findings on a totally different sample of college-age males. The results presented here clearly show a tendency to lose fat on one part of the body while gaining fat elsewhere.

METHODS AND MATERIALS

The present investigation is based upon measurements of the fat-plus-skin shadow on standardized teleoroentgenograms of 338 white subjects aged 12.5 to 65 years of age.

One hundred and twenty-four of the subjects, 20 years of age and younger, were regular participants in the longitudinal

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studies of the Fels Research Institute. The adults were parents of participants in the longitudinal studies and in some cases had been participants as well. A group of 73 male college students aged 21.0 to 22.9 years is included for comparison, but these data are presented separately from the others since the students constitute a different population sample.

The x-rays were taken at a 6-foot tube-to-film distance at 15 miliampere seconds, and at kilovoltages ranging from 42 to 80 PKV depending upon part thickness. Dupont type 508 film and Patterson "par-speed" screens were employed to minimize exposure. A "Videx" double-diaphragm adjustable cone was similarly used to restrict the area of irradiation.

Subject positioning for the postero-anterior trochanteric view² and the latero-medial lower leg view followed Garn ('54). Measurements were made, at right angles to the skin surface, using a pinpoint-tip vernier caliper as described by Garn and Saalberg ('53). Tracings of sample x-rays showing the "sections" as they appear on the film and the location of the measurements are reproduced in figure 1.

Because fat thickness distributions are highly skewed, the 5th, 50th and 95th percentiles were computed instead of the usual means and standard deviations. However, since the F test for trend and E^2 (the correlation ratio without bias) both involve the assumption of normality (cf. Edwards, '47), the skewed distributions were converted into normally-distributed T values. Analysis of variance, F, and E^2 as well as the *t*-tests were conducted using normalized T-scores.

It should be noted that the present findings refer to a particular population sample. While it is likely that the findings are applicable to other white populations, generalization should be accompanied with caution.

² Trochanteric fat was selected as a measure of general fatness since, of all the measurements we have studied to date, Tr_2 is (1) most highly correlated with weight and (2) shows the greatest communality with other fat thicknesses (cf. Garn, '54; Garn, '56b).

FINDINGS

As shown in table 1, fat on the anterior part of the leg *decreases* from the second to the fourth decade, while trochanteric fat markedly *increases* over the same time span. These contrasting trends hold for both sexes. And while the college-

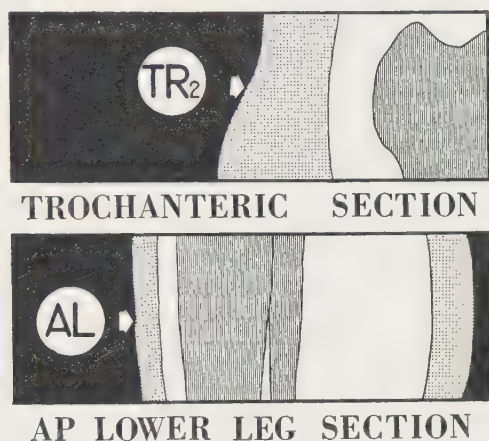


Fig. 1 Examples of trochanteric section² and anterior leg section x-rays used in this study. The arrows point to mid-trochanteric fat (Tr_2) and anterior leg fat (AL) respectively. For details on subject positioning, see Garn ('54) p. 60-62.

TABLE 1

Changes in anterior leg fat and trochanteric fat in males and females aged 12.5 to 60 years

SEX	MEDIAN AGE	NO.	ANTERIOR LEG FAT Percentiles			TROCHANTERIC FAT Percentiles		
			5th	50th	95th	5th	50th	95th
M	14.5	44	2.8 ¹	4.2	8.8	5.7	10.6	35.3
M	17.5	13	2.0	3.2	5.3	6.7	9.0	17.3
M ²	22.0	73	2.4	3.7	6.7	6.1	12.5	35.8
M	32.0	35	1.6	2.6	4.3	5.1	13.7	26.6
M	47.5	42	1.6	2.5	4.0	8.5	17.2	28.6
F	14.5	47	3.7	5.5	8.6	9.3	20.2	41.3
F	17.0	20	3.5	5.6	7.9	7.8	21.0	49.2
F	29.0	39	2.4	4.0	8.6	15.0	25.1	44.3
F	46.6	25	2.3	3.9	9.2	17.1	33.4	41.8

¹ All fat thickness in millimeters.

² College students aged 21.0-22.9 years.

age males represent a separate population sample, their anterior leg fat is significantly larger than in the older adult males, and their trochanteric fat is similarly significantly smaller.

Several tests for trend confirm the reality of these changes. The F test was significant at $p = .01$ or better for all four trends: ϵ^2 was similarly significant. Thus the four-decade

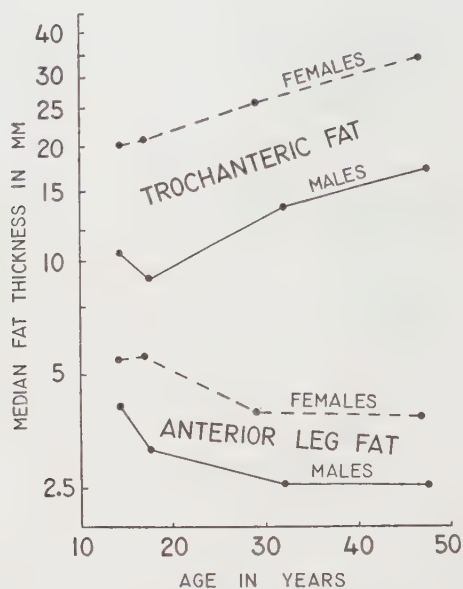


Fig. 2 Log/linear plot showing concurrent fat loss and fat gain in both sexes. Though the females were consistently fatter, changes in trochanteric fat and anterior leg fat were proportional.

decrease of 1.6 mm in anterior leg fat, stands in striking contrast to the four-decade increase of 7 and 13 mm in trochanteric fat.

Since the females were fatter to begin with, and gained trochanteric fat more rapidly, the semi-log plot shown in figure 2 was helpful in portraying relative changes. Throughout, females were fatter, but the changes were proportional. The slope of each pair of lines was approximately the same. Stated

somewhat differently, men and women paralleled each other in the contrasting paths of fat-loss and fat-gain.

Analysis of a limited number of cases followed in longitudinal fashion from the late teens through the early twenties provided examples of these changes in individuals. Some of the subjects, however, gained in anterior leg fat, or lost trochanteric fat during this short period: the total number so studied (17) is as yet too small for detailed analysis. It is clear that, on a group basis, anterior leg fat decreases 30–40% while trochanteric fat increases 65–70% but this need not be true of all individuals in the Fels population.

DISCUSSION

As shown previously, simultaneous fat-loss and fat-gain may be demonstrated for both sexes, in the fat on the anterior leg and over the greater trochanter. While trochanteric fat rises steadily, anterior leg fat decreases and then remains constant in men and women alike. These contrasting trends are indicative of an adult rearrangement of fat, in part separate from the common phenomenon of adult fattening.

These findings are by no means identical with the reports by Edwards ('50, '51) and Skerlj ('54) based on Edwards' data. Their decreases in leg fat represented a decrease in the percentagewise contribution of leg fat to the total summation. Since central fat adds more rapidly than peripheral fat, peripheral fat may decrease *percentagewise*, even though absolute values actually increase.³

Again, the small decrease in medial leg fat (0.5 mm or 10%) reported by Reynolds for males alone between the late teens and adulthood, is not part of the phenomenon considered here. As we have shown previously, medial leg fat increases during the adult years in both sexes (Garn and Saalberg, '54; Garn

³ Skerlj ('54, p. 333) wrote that "Considering both extremities the general tendency in both sexes is to lose subcutaneous fat, particularly from the distal parts." This statement is manifestly incorrect except where leg fat is expressed as a percentage of the total summation. Absolute values of leg fat increase with increasing age and weight (Garn and Harper, '55; Garn, '56b).

and Harper, '55), whereas anterior leg fat here decreases over the same time period.

The possibility that these findings are due to sampling errors, or changes in measuring technique is minimal. The adults and children in this study (with the exception of the college students as previously noted) come from a single population. In fact the younger subjects are the progeny of the adults, and the women studied here are espoused to the men. The men, in turn, were x-rayed during the spring and summer of 1953 (see Garn, '54), the women were studied during 1954 and 1955 and the measurements made in 1956, while the data on immature individuals were collected for the most part from 1952 to 1955 and measured in 1956. Finally, the college students were studied during the winter and spring of 1955-56. Thus no systematic changes in measuring technique could account for the phenomenon observed here, in which the sexes clearly agree.

So far, none of the remaining 10 fat thicknesses that we regularly study in adults has behaved like anterior leg fat. All others appear to increase with age and with increasing fatness at rates peculiar to the particular deposit site (cf. Garn and Harper, '55). However, notice should be taken of several trend reversals noted in our investigations. Starting first with the infant, there is the almost universal tendency for medial and lateral leg fat to decrease, at some time between the 6th and 12th month, despite a general gain in size and fat (Garn, '56a). Again superciliary scalp fat reaches a maximum in the first year of life, and decreases for a number of years thereafter (as shown in the unpublished work of R. W. Young). In adulthood there is a sex reversal in scalp thickness: it is the male who seemingly has the most scalp fat (Garn, Selby and Young, '54). Finally, the maturing female not uncommonly gains breast fat and trochanteric fat while diminishing her subcutaneous fat reserves elsewhere.

Ordinarily we may expect fat thicknesses to be covariant. At all age levels subcutaneous fat thicknesses are positively correlated, with values of r up to 0.95 (Reynolds, '50; Garn,

'54; Garn, '56b). During rapid weight loss all fat layers contribute, with the thickest deposits tending to lose the most (Garn and Brožek, '56). But in transitional life phases there appear to be rearrangements in the *telea subcutanea* that markedly contrast with the general trend. What mechanism is involved in the present case remains obscure: whatever it is, it clearly operates in both sexes.

SUMMARY

1. The thickness of the subcutaneous fat-plus-skin shadow was measured on standardized teleoroentgenograms of 338 white subjects aged 12.5 to 65 years.

2. Expectably, trochanteric fat increased in both sexes with the larger absolute increase observed in the females.

3. Anterior leg fat diminished in both sexes, and to the same degree, reaching a near-minimum in the fourth decade.

4. This phenomenon (fat loss during fat gain) was statistically significant by the F and ϵ^2 tests, and indicated an adult rearrangement of fat.

5. In discussing the subject, attention was called to trend reversals in infancy, at adolescence, and in specific fat depot sites in the adult.

6. No evidence as to the underlying mechanism for this adult rearrangement was found.

ACKNOWLEDGMENTS

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SHOVEL-SHAPED INCISORS AND A FEW OTHER DENTAL FEATURES AMONG THE NATIVE PEOPLES OF THE PACIFIC

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INTRODUCTION

One of the significant problems in the study of the native peoples of the Pacific is the problem of Mongoloid influence in that area. Such influence is of importance not only to the racial but also the cultural history of its peoples, since the introduction of many elements of culture can be attributed to this source. In the older studies, Mongoloid infiltrations were traced on the basis of a certain number of descriptive or some metric characteristics such as the cephalic index. But while in Indonesia and Micronesia Mongoloid elements are characterized by brachycephaly, and while in Polynesia the brachycephalic element has been explained by Shapiro ('43) as an Asiatic heritage, brachycephaly is not at all correlated with Mongoloid features in certain parts of Melanesia. Thus, brachycephaly as a tracer of Mongoloid influence is only of geographically limited importance, to say nothing of its considerable environmental adaptiveness which deprives it of much of its value for purposes of racial classification. The use of the B-factor, on the other hand, as a possible serological tracer of Asiatic influences is not generally applicable to the entire area of the Pacific either. For while Mongoloid features and the presence of the B-factor coincide in certain parts of the western Pacific, they do not do so in Polynesia, where some Mongoloid influences are obvious in descriptive and perhaps in metric characteristics, but where the B-factor is generally absent. In view of the shortcomings and geographical limita-

tions of these characteristics, the feature of shovel-shaped incisors was used in the present study. Its high frequency among Mongoloid peoples has been recognized by Hrdlička ('20) and many later writers (Montelius, '33; Morse, '37; Nelson, '37-'38; Stevenson, '40; Goldstein, '48; Pedersen, '49; Tratman, '50; Lasker, '51). Moreover, a certain number of other dental features, which in the opinion of Tratman ('50) are typical of the Mongoloid race, were also studied.

MATERIALS AND METHODS

In the present paper, a total of 605 individuals with 1,995 upper permanent incisor teeth from various parts of the Pacific was used. Only a small number of skulls in the Amer. Museum of Natural History could be included, since teeth with single roots are easily lost in skeletal material. By far the larger number of observations were carried out on casts made among living natives of the Pacific. I should like to express my sincere thanks to Drs. E. W. Udick, Fiji, W. Ledowsky, Nauru, van der Veur, Sorong, Dutch New Guinea, J. P. Walsh, Otago, Patrol Officer A.R.M. Skewes, Papua, and to the Government personnel at Honiara, who have all helped me in making the casts. In all cases genealogical data through two generations were collected in order to be sure of the exact tribal and racial affiliation of the person.

In a dental study comparing Indian immigrants with Mongoloid Malayans of the Malay Peninsula, Tratman ('50) found that Mongoloid upper incisors are characterized by a faint to fairly well marked development of lateral ridges running gingivo-incisally on the labial surface. The Mongoloid group showed also a greater frequency of two shallow axial grooves on the labial surface dividing it into three parts, the grooves being deepest in the middle third of the surface and fading out incisally and gingivally.

Tratman ('50) as well as Pedersen ('49) found that the maxillary lateral incisors are less frequently absent in Mongoloid than in other racial groups, and there are a number of studies on the genetic character and racial distribution of

numerical variations in the upper lateral incisors (Ashley Montagu, '40, with extensive bibliography; Hrdlička, '21; Goldstein, '48). Ashley Montagu ('40) has worked out a classification for the various degrees of reduction in lateral incisors. He differentiates between slightly reduced, reduced, and markedly reduced or peg-shaped types, apart from cases of missing or supernumerary lateral incisors. It appears from Ashley Montagu's studies that deficiencies of lateral incisors are very rare among Australians, Melanesians, and Bantu ('40). Tratman ('50) found that Mongoloids are characterized by a very frequent rounding of the distal angle of the incisal edge of the upper laterals, reminiscent of the distal slope of a canine; or, that the slope can occur distally and mesially, conveying a caniniform aspect to the lateral incisor. In the present study a distinction has been made between distally, mesially, and disto-mesially rounded (caniniform) lateral incisors, and such incisors in which a rounding is absent, so that they are bilaterally angular. Finally, Tratman pointed out that the greatest width of the central incisors is usually slightly further gingivally from the incisal edge in Mongoloids than in his Indo-European sample of Indian immigrants. Such an incisor type corresponds most closely to Williams' type I (Williams, '14; see also Shaw, '31), in which the two borders are parallel or nearly so for half or more of their length from the incisal edges. Williams' central incisor type II is widest at the incisal edge with the lateral lines converging so markedly that they would meet in most instances near the end of the root; and in his type III, the mesial and distal borders form a slight double curve.

All the above mentioned features were analyzed in the present study. The observations are contained in tables 1 and 2. The two sexes are not separated. The degree in the development of the lateral ridges in shovel-shaped incisors was graded as slight, medium, and marked according to Hrdlička's classification ('20) and according to Pedersen's standards ('49; see also Koski and Hautala, '52). In terms of Dahlberg's classification as worked out in his Plaque P 1, our

TABLE I

TRIBAL GROUP	INDONESIA	MICRONESIA	POLYNESIA	FIJI	NEW GUINEA	PAIUM	SOLOMONS	MELANESIA	AUSTRALIA
No. of incisors	57 (28 cent. 29 lat.)	143 (71 cent. 72 lat.)	80 (37 cent. 43 lat.)	892 (466 cent. 426 lat.)	171 (83 cent. 88 lat.)	247 (101 cent. 146 lat.)	334 (166 cent. 168 lat.)	24 (10 cent. 14 lat.)	47 (22 cent. 25 lat.)
Shovel-shaped									
Slight %	57	43	45	34	45	13	32	50	51
Medium %	36	31	26	12	4	6	9	..	13
Marked %	..	4	8	2	..	..	..	..	..
Total % of sh.-sh. incisors	93	78	79	48	49	19	41	50	64
% of medium and marked sh.-sh. incisors	36	35	34	14	4	6	9	..	13
Labial lat. ridges									
No. of cases	5 (1 cent. 4 lat.)	54 (25 cent. 29 lat.)	10 (5 cent. 5 lat.)	111 (29 cent. 82 lat.) *	6 (3 cent. 3 lat.)	3 (2 cent. 1 lat.) *	48 (19 cent. 29 lat.)	1 (lat.)	1 (cent.)
Labial lateral ridges %	9	38	12	13	4	1	14	4	2
Labial axial grooves. No. of cases	9 (7 cent. 2 lat.)	49 (33 cent. 16 lat.)	14 (10 cent. 4 lat.)	156 (141 cent. 15 lat.)	6 (4 cent. 2 lat.)	2 (cent.)	46 (28-cent. 18 lat.)	1 (cent.)	7 (5 cent. 2 lat.)
Labial axial grooves %	16	34	17	17	4	1 **	14	4	15
No. of cent. in- cisors available for Williams'									
types	38	72	50	470	84	96	162	10	21
Williams' type I %	53	67	44	50	50	29	33	40	19
Williams' type II %	11	7	34	21	7	41	36	40	71
Williams' type III %	37	26	22	30 * out of 882 (460 cent. 422 lat.)	43	30 * out of 261 (108 cent. 153 lat.)	31	20	10

** out of
out of

TABLE 2

TRIBAL GROUP	INDONESIA	MICRONESIA	POLYNESIA	FJI	NEW GUINEA	RALUM	SOLOMONS	MELANESIA	AUSTRALIA
No. of incisors	57 (28 cent. 29 lat.)	143 (71 cent. 72 lat.)	80 (37 cent. 43 lat.)	892 (466 cent. 426 lat.)	171 (83 cent. 88 lat.)	247 (101 cent. 146 lat.)	334 (166 cent. 168 lat.)	24 (10 cent. 14 lat.)	47 (22 cent. 25 lat.)
<i>Upper laterals:</i>									
Slightly reduced cases	8	8	17	110	5	24	34	..	3
and %	28	11	40	26	6	16	20		
— reduced cases	3	4	4	21	..	4	10	..	12
and %	10	6	9	5		3	6	..	..
— markedly red. peg-shaped cases	..	3	..	5	..	3	1	1	2
and %	..	4		1		2	1	7	8
— missing cases	..	2	..	15	..	..	2	..	..
and %	..	3		4			1		
— supernumerary cases and %	..	..	..	..	1	2	1	..	..
					11	1	1		
<i>Central incisors:</i>									
Missing cases	..	..	..	2	..	..	..	..	..
and %				0.43					
% of reduced laterals	38	24	49	36	6	21	28	7	20
Mesially rounded laterals, cases	..	..	..	..	..	2	1	..	..
and %						1	1		
Distally rounded laterals %	42	26	20	11	7	10	1	..	20
Bilaterally rounded (canini-form) laterals %	11	12	8	4	5	5	6	18	..
Angular laterals %	47	62	72	85	88	84	92	82	80

"slight" corresponds to Dahlberg's type b, "medium" to his types c and e, and "marked" to his types f, g, and h. An extreme degree such as Dahlberg's type d was not observed in the present material. Absence of shovel-shape corresponds to Dahlberg's type a. Tratman's type with mesial and lateral ridges on the labial surface, corresponds to Dahlberg's "double-shovel shape" as illustrated on the labial side of his type d. No transverse sections of original specimens were made to show the involvement of the dentine in the formation of the lateral ridges. The finding of previous writers (Hrdlička, '20; Jonge-Cohen, '26; Chappel, '27; Stevenson, '40; Pedersen, '49; Lasker, '45, '51) that the lateral incisors are affected a little more frequently and have slightly more pronounced marginal ridges than the central incisors, is confirmed also by the present study.

DISCUSSION

In view of the occurrence of shovel-shaped incisors in *Sinanthropus* (Weidenreich, '37, '46) and of the fact that the peoples of the Pacific were originally derived at various periods of time from the Asiatic mainland, a review of the prehistoric dental material in the Pacific would seem to be extremely desirable. Such a review might shed some light not only on the chronology of Mongoloid infiltrations in the Pacific, but also on their routes of penetration. However, prehistoric skeletal material is very limited in the Pacific, and in the existing material upper incisor teeth are extremely rare. If present, the lingual surface is not described by the recorders. In a number of cases, the present whereabouts of the material is not known, though some of it could perhaps be traced by long and determined efforts. The only record this writer has been able to find in the literature is that of the discovery of a few human teeth made by Dubois in the Lida Ajer Cave in Central Sumatra. One upper central incisor shows the shovel-shaped form in a medium degree (Hooijer, '48, '52). However, there is no agreement on the dating of this find. Weidenreich ('42) considers it as Pleistocene because

the accompanying orang-utan material "was a contemporary of *Sinanthropus*." But Hooijer ('48) believes that it is *Homo sapiens* since the incisor is smaller than in *Sinanthropus* and since the longitudinal axis of its crown and that of the root form an obtuse angle as in recent man (Jonge-Cohen, '20), whereas in the *Sinanthropus* incisors the axis of the crown and that of the root lie in the same direction (Weidenreich, '37). (Tratman, '50, considers such a greater axial curvature to be a characteristic of the Mongoloid race.) Moreover, since there is no other evidence of the presence of man at Lida Ajer, and since most of the teeth have been gnawed by porcupines, Hooijer believes that the location of the deposits in the caves might be due to water transportation or the work of some carnivores.

The observations on shovel-shaped incisors contained in table 1 can be compared with a few published data. These data are, however, extremely limited, since existing dental studies in the area of the Pacific concentrate almost entirely on the problem of caries. Thus, Genet-Varcin ('51) noticed shovel-shaped incisors in 5 Aeta skulls out of a sample of 7, paralleling the high frequency of the Indonesian sample here used. A sample of 86 pre-Spanish and early post-Spanish skulls from Guam studied by Leigh ('30) (the number of teeth not stated) gives a frequency of only 22% of shovel-shaped incisors (10% slight, 10.5% medium, 1.5% marked, 78% absent). This differs markedly from the observations made on the Micronesian sample of this study. Chappel ('27) who studied 47 (28 male and 19 female) Hawaiian skulls says of the male skulls: 2 of these show shovel-shaped incisors in a medium degree; 1, small ridges on both central and lateral incisors; and 6, small ridges on the lateral incisors only. Of the 19 female skulls, 2 have well-marked shovel-shaped incisors; in 1, they are medium, and 1 shows small, lateral ridges on the lateral incisors only. Of the 47 skulls examined, 13 (27.6%) show a tendency toward the shovel-shaped incisor, but 8 of these exhibit it in a very slight degree. This low percentage differs from the observations made by Hrdlička ('20), who, in a sample of 59

Hawaiian individuals, finds shovel-shaped incisors in 93.2% of the cases (77.9% medium, 15.3% slight, 6.8% absent); but it resembles somewhat the results obtained by Wissler ('31) on a much larger sample. In 1201 upper incisors from Hawaii, he found slightly developed shovel-shaped types in 24.05%, and medium and marked types in 25.14%. The Polynesian sample here used gives a frequency much closer to that of Wissler than to those of Chappel and Hrdlička. Janzer ('27) who studied 258 upper incisors of the coast people of the Gazelle Peninsula (the area from which the Ralum sample of this study is derived), mentions the occasional occurrence of shovel-shaped incisors without however giving any statistical data. Klaatsch ('08), who studied 90 skulls from various parts of Queensland, does not say anything about shovel-shaped incisors, but his photographs (figs. 75, 80, 83) not taken with special focus on the incisor teeth however, show two moderate and one marked case of shovel-shaped incisors. Campbell ('25) who studied 630 skulls from various parts of Australia, examining about 10,500 teeth (without however specifying the number of upper incisors), and who might have given valuable information on this subject, says only (p. 28): "this shovel-shape of upper incisors is by no means a characteristic of the Australian's teeth. It occasionally occurs, but very rarely in an accentuated form." This lack of statistical precision is regrettable, since the custom of tooth removal practiced widely in various parts of Australia deprives the student most frequently of the upper incisors. And it fails to shed any light on the validity of the observations made on a very small Australian sample in this study which gives a rather unexpectedly high frequency of shovel-shaped incisors. The curiosity of the student of this subject is even more aroused by a statement made by Adam (Unpublished Thesis), who studied 56 Tasmanian skulls. He says of the upper central incisors: "The lingual surface is concave in all directions with definite mesial and distal marginal ridges, though in some cases the lingual surface tends to convexity," and on the lingual surface of the lateral incisors "the marginal ridges are usually more pro-

nounced." Moreover, some of Steadman's photographs of Tasmanian skulls ('37, nos. 1096, 1098, 1099, 1406, 1417) show shovel-shaped incisors, but nothing is mentioned by the author on the subject.

It is possible that some of the above contradictions on the frequency of shovel-shaped incisors are due to the use of different standards. Because of the methodical or numerical limitations of these studies, they have not been taken into consideration for any conclusions regarding the entire area of the Pacific, and such conclusions are based mainly on the data presented in this paper. This has the advantage of applying uniform standards to the entire sample.

On the basis of descriptive and some metric features used in earlier studies it appears that, generally speaking, the intensity of Mongoloid influences in the Pacific decreases from West to East, i.e. from Indonesia, through Micronesia, to Polynesia. In Melanesia, particularly the outskirts of that area have been infiltrated racially by non-Negroid peoples, and their influence is very weak in north-western Australia. This situation is clearly reflected in the frequency of shovel-shaped incisors (table 1) which is highest in Indonesia and decreases through Micronesia and Polynesia with a remarkable drop in Melanesia. Actually, if the figures for the percentage of the total number of shovel-shaped incisors are taken into consideration, it appears that the frequency is slightly, though statistically not significantly higher in Polynesia (78.75%) than in Micronesia (78.32%), because of the relatively higher frequency of slightly developed shovel-shaped incisors in the Polynesian sample. It seems doubtful however whether the inclusion of cases with a slight development of the shovel-shape incisor type is of any racial significance. For in a sample of white Americans in which the frequency of well developed shovel-shaped incisors was only 14%, Lasker ('51) found that half the population showed some tendency to manifest mesial and distal ridges. If, in the present sample, only the cases with medium and marked shovel-shaped incisors are taken into consideration, the de-

crease in their frequency appears clearly from Indonesia, through Micronesia, to Polynesia. However, in view of the small size of the samples, the exact magnitude of these regional differences will have to be established by future studies. In the Melanesian area, the islands most closely adjacent to Polynesia, namely Fiji, significantly range highest in the frequency of shovel-shaped incisors, followed by the Solomon Islands further to the west. All students of the Fiji and Solomon Islands have recognized the influence of non-Negroid peoples in these two areas, although there is no general agreement as to whether it is due to a Polynesian backwash or to west-to-east migrations of the original Polynesian migrants. For the present study this controversy is however not important, and could not in any case be solved by a study of the dental features under consideration. The Negroid areas of Ralum and New Guinea characteristically have the lowest frequency of shovel-shaped incisors. The sample headed "Melanesia" is so heterogeneous in origin and so small that it is certainly not significant. The frequency in the Australian sample (skulls in the Amer. Mus. of Natural History) is surprisingly high whether the cases of slight shovel-shaped development are included or not. This could be due to the small size of the sample or perhaps to a derivation of this material from northwestern Australia with some Indonesian influence. The question must be left open.

The decrease in the frequency of shovel-shaped incisors from Indonesia, through Micronesia, to Polynesia paralleling the west-to-east cline of Mongoloid features in general in the Pacific, is clearly incompatible with Heyerdahl's assumption ('50, '52) of an American origin of the Polynesians. A few incomplete data taken from the literature (table 2) show that the frequency of shovel-shaped incisors among American Indians is not only much higher than in Polynesia, but even higher than in the western parts of the Pacific. Thus, the dental observations confirm the opinion generally held that the Polynesians came originally from Asia.

As far as labial lateral ridges and labial axial grooves are concerned which Tratman considers as typical features of Mongoloids, their frequency is indeed very low in the Negroid samples from Ralum and New Guinea, and labial lateral ridges are also very rare in the Australian sample. In all the other groups manifesting a greater or lesser Mongoloid component, these two features are much more frequent. But while there is a certain concordance in frequency between these two features

TABLE 3

TRIBAL GROUP	NO. OF INDI- VIDUALS	NO. OF TEETH	ABSENT	SLIGHT	MEDIUM AND MARKED	AUTHOR
			%	%	%	
Sioux Indians	116		...	1.7	98.3	Hrdlička, '31
Early Indians, Texas	124		...	4.9	95.1	Goldstein, '48
Indians (Pecos Pueblos)	124		13.7	..	86.3	Hooton, '30
Pecos Indians		662	1.8	8.75	89.45	Nelson, '37-'38
Pueblo Indians	21		...	..	97.5	Dahlberg, '51
Pima	283		0.35	6	89.55	Dahlberg and Mikkelsen, '47
Indian Knoll	30		...	..	98.5	Dahlberg, '51
Indians		577	1	7	92	Hrdlička, '20
Indians		5135	...	14.5	85.5	Wissler, '31
Eskimo		77	...	7.5	92.5	Hrdlička, '20
East Greenland Eskimo	116		1.7	14.7	83.6	Pedersen, '49
				(slight to med.)	(marked)	

themselves (except in the Australian sample) no such concordance appears between them and shovel-shaped incisors. The frequency of labial lateral ridges is higher in the lateral than in the central incisors of all the larger samples, paralleling the higher frequency of shovel-shaped forms in the laterals. Labial axial grooves, on the other hand, are much more frequent in the central than in the lateral incisors.

Although it is likely that a slight or medium reduction of the lateral incisors is not of any racial significance in the

Pacific, the above data show the rarity of peg-shaped, missing, or supernumerary upper laterals in both the more Mongoloid and the more Negroid samples. This confirms Tratman's as well as Ashley Montagu's findings of the rarity of such anomalies, but obviously makes this feature useless as a tracer of Mongoloid influences. Data on the extremely rare numerical variability of the lateral incisors among the peoples of the Pacific have been published by Ottogy ('08), Hrdlička ('21), Schwarz ('25), Campbell ('25), Steadman ('39), Ashley Montagu ('40), and Sinclair, Cameron and Goldsworthy (no date). Since the numerical variability of upper lateral incisors can be studied on the basis of the alveoli alone, 427 skulls without incisor teeth (61 from Indonesia, 14 from Micronesia, 126 from Polynesia, 204 from Melanesia, and 22 from Australia) in the American Museum of Natural History were studied in addition to those contained in table 2. In only one female Maori skull (AMNH no. 2006) were both laterals missing. The findings of Ashley Montagu ('40) and Röse ('06) that the variability of lateral incisors (peg-shaped, missing, and supernumerary) is slightly higher in females than in males, is confirmed in the present study. For among 425 male individuals, 19 or 4.47% show such variations, while among 180 females, there are 11 individuals or 6.11%. These figures may contain a slight error however, since they are at least partly based on skulls in which sex determination is hazardous. Moreover, since only casts but no X-rays were taken on the living, the absolute figures on congenitally missing laterals here given might be slightly vitiated by cases of impaction.

Tratman's contention that Mongoloids are characterized by a higher frequency of distally or disto-mesially (caniniform) rounded lateral incisors, is fully confirmed by the present data. These two types are much more frequent in the more Mongoloid areas of Indonesia, Micronesia, and Polynesia than in the Negroid areas of Melanesia. And here, as in the case of shovel-shaped incisors, a west-to-east cline can be observed ranging from Indonesia, through Micronesia, to Polynesia. (The slightly higher frequency of the caniniform type in

Micronesia (11.59%) if compared with Indonesia (11.11%) is statistically not significant and disappears if the distally and disto-mesially rounded cases are combined.) The high figure for "Melanesia" can again be ignored because of the heterogeneity and small size of the sample; and the high frequency of the distal rounding in the Australian material remains again an open question because of the small size of the sample and the uncertainty of its exact regional derivation. The bilaterally angular lateral incisor type on the other hand, increases steadily from Indonesia, through Micronesia, to Polynesia, and shows its highest frequency in Negroid Melanesia. The mesially rounded lateral incisor not mentioned by Tratman is indeed not racially significant, as appears from table 2.

If the above data are analyzed with regard to Williams' three types of central incisors, it appears that type I is the most frequent in the Mongoloid infiltrated areas of Indonesia, Micronesia, and Polynesia. This confirms Tratman's view according to which the greatest width of the central incisors is usually further gingivally from the incisal edge in Mongoloids. In fact, in many instances in this category the parallel arrangement of the two lateral borders extends to an extremely high point up gingivally. It is true that no cline can be observed in Indonesia, Micronesia, and Polynesia paralleling that of shovel-shaped incisors for instance, and in the Melanesian samples of Fiji and New Guinea this type is even more frequent than in Polynesia. But if the values are pooled, it appears that the average percentage of this type is 55% in the more Mongoloid areas of Indonesia, Micronesia, and Polynesia, and only 40% in the Negroid areas of Melanesia (Fiji, New Guinea, Ralum and the Solomons). The importance of Williams' type II lies in the fact that Azoulay and Regnault (1893) have considered it as typical not only for anthropoid apes, but also for Negroes and "Papuan." Shaw ('31) has however found no evidence in his sample of Bantu incisors to support this view, but found all three of Williams' types to be present, with a markedly higher frequency of type III. However, he hesitates to ascribe any specific significance to this

fact because of the small size of his sample (100 incisors). In the sample here used, this type appears with an extreme degree of local variation without any apparent trend. While the type is rare in Indonesia and Micronesia, its frequency is very high in the Polynesian sample used. This observation is confirmed by Radwanski-Szinagel ('54) who found this type to be very frequent among Easter Islanders, without however giving any statistical data. If the non-Negroid areas of Indonesia, Micronesia, and Polynesia are again pooled for this feature, they give an average of 17% against 26% in the Negroid areas of Melanesia. But in view of the extreme local variability, it is doubtful whether such an average value has much significance. Type III occurs in Indonesia, Micronesia, and Polynesia in what at first sight would seem to be a west-to-east cline. This is however more apparent than real, for the local values in Melanesia are both higher and lower than those outside of Melanesia without showing any particular trend. But the pooled values of Melanesia give an average of 33% for type III against 28% in the combined area of Indonesia, Micronesia, and Polynesia. The greater frequency among the Negroids of Melanesia is reminiscent of Shaw's findings that type III is the most frequent type among the Bantus. If all areas of the Pacific are taken together, type I appears in 47%, type III in 31%, and type II in 22% of the cases. This order in the frequency of Williams' types, I-III-II, appears also if the non-Negroid areas of Indonesia, Micronesia, and Polynesia, and the Negroid areas of Melanesia are treated separately. For in the non-Negroid area the order is: I 55%, III 28%, II 17%, and in Melanesia it is: I 40%, III 33%, II 26%. This seems to indicate that, in spite of some limited racial significance of Williams' types, the order I-III-II prevails universally in the Pacific. Whether this observation applies to modern man in a more general sense should be taken up in a future study. Only the small Australian sample seems to contradict this order, giving an order of II-I-III. But a much larger sample is needed to establish the validity of this observation. The small sample from "Melanesia" has not been considered in the above computations.

SUMMARY

A certain number of permanent upper incisors from various parts of the Pacific were studied. Shovel-shaped incisors, labial lateral ridges, labial axial grooves, and rounding of the lateral incisors, all of which, in the opinion of previous writers, are typical of the Mongoloid race, appear in a much higher frequency in the more Mongoloid than in the Negroid groups of the Pacific. A previously assumed Mongoloid cline from Indonesia, through Micronesia, to Polynesia, is confirmed by a west-to-east cline in the frequency of shovel-shaped types and the rounding of lateral incisors. Such a cline and the fact that shovel-shaped incisors are much more frequent among American Indians than even in the western Pacific, is incompatible with Heyerdahl's claim of an American origin of the Polynesians.

Numerical variability in lateral incisors is useless as a tracer of Mongoloid influence, since this feature is equally rare in Mongoloid and Negroid groups. The frequency of Williams' types in central incisors appears in the order of I-III-II among Mongoloid and Negroid groups alike. The question arises therefore whether or not this order is universally present in recent man.

It is fully recognized that many of the samples used in this study are rather small and unevenly distributed. They should be greatly increased and geographically expanded in the future. However, it is hoped that this study will represent the first step towards an odontological anthropology of the Pacific.

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BRIEF COMMUNICATION

SAGITTAL LINES AND CRESTS

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Irony is clearly out of place in scientific literature, and probably I have only myself to blame for the fact that Riesenfeld ('55) begins his paper on "The variability of the temporal lines" by attributing to me a view about the posture and carriage of the Australopithecines to which I would subscribe no more readily than I should to the proposition that the sun normally rises in the west. Part of the misunderstanding may, however, be due to the possibility that Dr. Riesenfeld has both read me and quoted me out of context—in this instance, both out of the context of the sentence concerned, and out of that of the whole argument of my essay (Zuckerman, '54). If this were the only shortcoming of his paper, no correction would be called for. Unfortunately, it is not. On page 600, I am correctly cited as stating that, in Primates, the "possession of a high sagittal crest presupposes the presence of a powerful and shelf-like occipital torus"—a statement which Riesenfeld apparently agrees. But he then goes on to write that the proposition "overlooks the remarkable degree of variability in the position of the temporal lines that can be found in recent man." This is a *non sequitur*. The existence of this variability in no way precludes the proposition; nor does the proposition imply that such variability does not exist. Moreover, the fact that the position of the lines in recent man "falls well within the range of variation of non-human primates" follows from the knowledge that the corresponding lines in many monkeys

normally do not approach each other any more closely relatively than they do in the human skull.

The main conclusion which Riesenfeld draws from these facts is, however, unwarranted. He writes that since the temporal lines "can move up as high as almost to meet in the median line, the appearance of a sagittal crest in *Australopithecus crassidens* loses a great deal of its specific quality and would seem to be only the extreme expression of this principle of variability."

Now taxonomy often depends precisely on the extent to which variable homologous characters express themselves. Many anatomists before Riesenfeld have failed to find in any human skull a sagittal crest of the kind that normally develops in the great apes and in certain species of monkey. Riesenfeld himself examined "several thousand" skulls in the American Museum, and selected for closer study the 66 in which the lines approached each other most closely. The minimum distance by which they were separated in one of the specimens was 7 mm; in another 30 mm; in 4 others, between 31 and 40 mm; and in 9 others, between 41 and 50 mm. Since even this assiduous investigation failed to reveal a single human skull in which a sagittal crest had developed, and in view of the failure of previous workers to discover such a specimen, any reasonable person who picked up a fragment of primate skull possessing a sagittal crest would clearly be justified in drawing the conclusion that it was not part of a human skull. Given the specimen's other characteristics were consistent with the diagnosis, it would obviously be more reasonable to suppose that the fragment was part of a skull of a great ape. In other words, the variability of the position of the temporal lines in no way affects the "specific quality" of the sagittal crest or its value in systematic diagnosis.

A further *non sequitur* occurs in the sentence which follows the statement in which Riesenfeld expresses a view contrary to this. "Since," he writes, "in man, an intertemporal distance absolutely and relatively smaller than in apes does not imply a deviation from the usual carriage of the head,

a small intertemporal distance with its extreme expression in the form of a sagittal crest would seem to have only very doubtful diagnostic value for postulating such a feature." From this one infers the suggestion that someone has argued that it is the presence of a sagittal crest which is indicative of the way the head is carried on the vertebral column. I do not know at whom the criticism is levelled. In the case of the essay to which Riesenfeld refers several times, the argument developed was (a) the presence of a sagittal crest presupposes a nuchal crest; (b) a nuchal crest may be present in the absence of a sagittal crest; (c) in so far as any inference about the carriage of the head can be drawn from features of the skull, the significant one would be the presence of a nuchal crest, the disposition and conformation of the planum nuchale, and the position of the occipital condyles relative to the antero-posterior diameter of the skull. The existence of a sagittal crest is secondary to this series of related propositions, and does not derive from them.

Riesenfeld finally observes that the occipital condyles are more central in the Australopithecines than in apes, "even though the magnitude of the difference in its position is a matter of controversy." Regardless of controversy, the fact remains that the position of the foramen magnum in those Australopithecines in which it can either be defined with some measure of precision, or in which it can be reasonably estimated, corresponds much more closely to that in the great apes, young or adult, than to its position in human skulls (Ashton and Zuckerman, '56).

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REVIEW

CULTURE AND HUMAN FERTILITY. A study of the Relation of Cultural Conditions to Fertility in Non-Industrial and Transitional Societies. By Frank Lorimer, pp. 510. \$4.50. With special contributions by Meyer Fortes, K. A. Busia, Audrey I. Richards, Priscilla Reining and Gorgio Mortara. Foreword by Frank W. Notestein. UNESCO New York: Columbia University Press. 1954.

Until comparatively recently the most technically competent demographers had little knowledge of and perhaps little interest in culture and social structure. On the other side, anthropologists—with occasional exceptions—lacked sophistication in the techniques of population studies, and, if they published demographic data other than crude estimates, tended to present information that was highly incomplete from the point of view of demographers wishing to make refined analyses or comparisons. The present volume is a happy step in the right direction. Professor Lorimer exhibits familiarity with a good deal of anthropological literature and with many of the principal concepts of cultural anthropology. The anthropological contributors in their turn show considerable knowledge of the problems faced by scientific students of populations. If the findings here published are not always satisfactory from the angle of both disciplines, this is because such collaborations are still in a pioneer phase.

The first 251 pages are devoted to "General Theory" by Doctor Lorimer. His formulations are somewhat bold and sweeping, and Professor Notestein in his foreword indicates that he, as a demographer, and Professor Firth (another member of the UNESCO committee), as an anthropologist, have reservations with respect to some of Lorimer's interpretations. However, Lorimer makes the tentativeness of his generalizations explicit at many points, and Doctor Notestein properly says that they have value as "hypotheses for research and revealing points at which more precise information is needed."

A brief sketch of Lorimer's central hypotheses will necessarily appear more dogmatic than is actually the case in his extended treatment. He postulates that corporate unilineal kinship groups generate stronger motives for high fertility than societies emphasizing the

nuclear family. Extended or joint families may also encourage frequent parenthood but less so than corporate kin groups. Cultural or social disorganization may increase or lower fertility depending upon whether the disorganization favors relaxation of restraints upon procreation or negative trends such as endemic disease of the reproductive organs (cf. Lessa, '55). Competitive military power as a central value increases tendencies toward high fertility in "perpetual groups of a corporate character." Positive religious sanctions for procreation are significant in some cultures. The lack of availability of effective and culturally approved devices for birth control is of course a meaningful variable. When social disorganization is succeeded by new modes of stable social life, rapid increases of population result. We may expect ". . . a doubling of the native population in Africa south of the Sahara during the next forty to fifty years—except where this is checked by chaotic social conditions or disease" (p. 249).

Lorimer makes many points that cultural anthropologists will applaud. He argues that one must be wary of broad generalizations about tribal societies and look rather at the specific cultural factors in each case. He criticizes studies where "the reproductive practices of particular societies are treated apart from the total social structures within which these practices are operative" (p. 20). Lorimer also notes that explanations in terms of biological needs, environmental conditions, and technological changes have yielded results less promising than were anticipated a few decades ago. Investigators must redress this balance by full attention to the details of social organization and to cultural values. However, in some instances Lorimer tends to accept situational determination. Thus he leans toward the view that the island location of Oceanic populations is the one common explanatory factor of "ambivalence in attitudes toward fertility" (p. 114; cf. also p. 81) characteristic of many Pacific Island cultures. Lorimer fully recognizes that his theory of the relation between culture and fertility "defines extreme types. In all actual societies there is some admixture in varying degrees of these contrasting relations" (p. 199). Familistic societies place high valuation on children—but not necessarily on large families. He thinks that the relations of religion to fertility are "so complex that no significant general conclusions appear that are capable of succinct formulation" (p. 203). In short, Lorimer generally deals discriminatively with cultural materials. And I detected only one ethnographic error: the implication that "mother rights" are emphasized at Taos (p. 78). Professor Lorimer's section is not, of course, merely abstract theory. He reviews much of the relevant anthropological data, especially from Oceania, Central Asia, and Africa.

The contributions in Part Two are rich in material, both substantive and methodological. I can list only a few illustrations. Fortes admits but does not explore the interesting possibility that local inbreeding "... may be a factor in local variations in reproductive performance which is masked in a sample taken over a wide geographical range even within the same tribe" (p. 260). In his own study he eliminates this bias by concentrating upon a limited homogeneous population. Fortes concludes that there is "perhaps a year" of "adolescent sterility" and that "this is related to physiological conditions that have not changed with changing social conditions during the past 40 years" (p. 298). Fortes suggests that his Ashanti investigations "show that volunteers who are well enough educated to understand the purpose of the investigation can, with suitable briefing and supervision, produce valuable and relatively accurate data" (p. 319). If education leads merely to the postponement of marriage for a few years, "... but not to changes in the ideals of parenthood, the effect on birthrates may be negligible" (p. 320). Busia, however, states the tentative hypothesis that educated members of the Gold Coast community (and city dwellers) show both postponement of marriage and declining fertility (p. 349). Richards and Reining present some excellent, concrete material on the problems of population field work among the Buganda and Bahaya (pp. 360-64). They report a very high rate of childlessness among the Buganda (31.6 per cent among married women over 45 years of age in the sample). Their summary of salient cultural differences between the Bahaya and Buganda is extremely pointed (pp. 392-93). Mortara concludes that the lack of decline in the Brazilian birth rate is a fundamentally biological phenomenon "with social factors only of secondary importance." His article gives a helpful digest of much fundamental material, hitherto available only in Portuguese.

Professor Lorimer would, I am sure, be the last person to claim that this volume constitutes a definitive treatise on the immensely complicated subject of culture and fertility. If, therefore, I call attention to some matters that seem to me to have been omitted or too lightly touched upon, my observations are not to be considered "critical" in the negative sense of that term. Rather, these are to be considered as "reminders" of *some* of the subjects, small and large, that would require treatment, or more extended treatment, in a comprehensive synthesis of contemporary knowledge. I shall deal with these issues on a canvas that goes, in part, beyond the UNESCO study's limitation to "non-industrial and transitional societies."

Only two pages (36, 146) in *CULTURE AND FERTILITY* refer to genetic factors in fertility. Yet population genetics is influenced

by mating systems and other culturally regulated practices (Kluckhohn and Griffith, '51; Schull, '53). Moreover, recent evidence (Stern, '55) suggests that even such genes as those of the A-B-O system, the population incidence of which is rather well established, imply differential propensities to illnesses relevant to life span and hence to reproductive potential. Improved transportation facilities and other recent cultural changes make possible a wider choice of mates, even in tribal societies, and this carries with it increased heterosis which some authorities consider important in fertility. Incidentally, Lorimer refers only once to "hybrid vigor."

On the predominantly cultural side, Lorimer does not deal with polyandry as a conscious adaptation to real or fancied shortage of food (cf. Aginsky, '39). In general, he rather underplays rational (or, at any rate, articulate) fertility control among "primitives." Thus, though he summarizes at some length Firth's excellent population data from Tikopia, he does not quote the statement that contraception, celibacy, and infanticide are practiced *fakatau ki te kai*, "measured according to the food" (Firth, '39, pp. 39-48). Lorimer likewise does not fully see that a practice such as abortion can be understood only in terms of the total cultural context rather than merely in terms of attitudes and culturally standardized behaviors related specifically to this practice (cf. Schneider, '55; Devereux, '55). Insufficient attention is given to cultural factors in class (e.g., Baltzell, '53), religious (e.g., Coon, '51) and other population segments. Lorimer does not examine a number of engaging hypotheses set forth by Coon ('51) such as the effects of frequent sweat baths at high temperatures upon the fertility of males. The relationships between epidemics or natural disasters, cultural beliefs and knowledge, and fertility also deserve exploration (cf. Cook, '55a, '55b). Finally, "culture and personality" aspects are hardly considered at all. This whole area would be greatly widened and deepened if the consequences of culture and situation were followed out into the conscious and unconscious psychology of individuals. To some extent this has been done in the series, "Social and Psychological Factors Affecting Fertility," appearing in the Milbank Memorial Fund Quarterly (see Kiser and Whelpton, '51; Herrera and Kiser, '51; Clare and Kiser, '51) — but not from the special "culture and personality" standpoint.

It is no deprecation of the valuable contribution of Lorimer and his contributors to say that very much remains to be done. Much more collaborative and specifically pointed field work is needed, of course. Particularly valuable would be more studies among populations like the Hutterites (Eaton and Mayer, '54) where fertility can be investigated with simultaneous regard for genetic, psychological, social,

and cultural variables. But much could be accomplished by exhaustive analysis of materials already available. As a stimulus in this direction, I shall list a number of publications, partly but not exclusively by anthropologists, that have come to my notice during the last few years. Many of these have appeared since Lorimer completed his writing, and I am aware that there are still others that have escaped me. For example, I have been told that McArthur has recently published a critical evaluation for the South Pacific Commission of all population data on the Pacific islands, but I have not been able to locate the reference. Taeuber ('55) has a most useful bibliography. Stycos ('55) has some thoughtful pages (7-22) on the relation of culture to fertility.

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REVIEW

YEARBOOK OF ANTHROPOLOGY, 1955. William L. Thomas, Jr., editor Wenner-Gren Foundation for Anthropological Research, Inc. New York, 1955.

The first Yearbook of Anthropology provides an over-all view of the present status of anthropology. The handsome volume is divided into six parts, and in each there is something of relevance to physical anthropology. The present Yearbook is considerably larger in scope than the Wenner-Gren Foundation's earlier *Yearbooks of Physical Anthropology*, though no attempt is made to reproduce significant articles nor to provide comprehensive bibliographies. A number of anthropologists were invited to prepare articles covering the contributions made in their respective fields between 1952 and 1954. They were free to address themselves either to the subject of recent progress or to some particular problem. A selective bibliography is appended to each article.

The guest editorial: "Evolution, Cultural and Biological" by Julian S. Huxley introduces the theme of the entire Yearbook: the relationship between biological and cultural concerns. Huxley contends that man has crossed the barrier between genetic and cultural evolution. As experiences are remembered and applied, purely biological adaptations became less important. "Once the cumulative transmission of experience was available, and accordingly, mind as well as matter became capable of self-reproduction and self-variation, it was inevitable that evolution would take place overwhelmingly in the cultural, rather than in the biological sphere . . ." Today mankind advances in the main through psycho-social modifications. Anthropologists, according to Huxley, should learn to approach their traditional data without a fixation on either organic or cultural change. He lists 6 types of analysis used by biologists that are also applicable to cultural phenomena: comparative, classificatory, differential, multivariate, constitutive and integrative.

One part of the Yearbook is given over to a regional round-up of Anthropological Reviews (1952-1954) for Europe and Southwest Asia. One is struck by the relatively narrow view of anthropology which prevails in most of this region. "Anthropology" means "physical anthropology" alone in most of it; and only in Italy,

Spain, and the British Isles does physical anthropology encompass as broad a field of enquiry as in the United States. For the paleoanthropologist there are accounts of new skeletal finds, such as Hotu in Iran and a new Mousterian child skeleton in Iraq. More timely is a reference to Hürzeler's reanalysis of the remains of *Oreopithecus bambolinii*, found near Florence nearly 80 years ago. Heine-Geldern reports that Hürzeler considers the specimens to be those of a Miocene hominid rather than of either a cercopithecoid or anthropoid. Blood-group research is being advanced in Jordan, Algeria, Greece, Spain and Great Britain. Among other ongoing projects is one on the similarities in reactions and gestures of identical twins in Vienna, and another in Yugoslavia where a highly inbred community is being studied genetically, anthropometrically and in terms of its paleodemography. No indications of degeneration have yet shown up. In several countries there is emphasis on applied physical anthropology, including identification, medical genetics, constitutional psychology, growth, colonial and military affairs, and clothing sizes.

Seven of the twenty-three papers have some relevance to physical anthropology. Only two of them, Macgregor's on "Anthropology in Government: United States" and Hoebel's on "Anthropology in Education" are disappointing. Macgregor fails to mention the considerably and increasing contributions of physical anthropologists in government-sponsored research; from identification of war dead to sizing of clothing for the armed forces; from testing for climatic adjustment to the establishment of standards for child health and development. Hoebel, commenting on the apparent lack of interest in educational goals on the part of American anthropologists, misses the relatively large amount of recent stock-taking by professional physical anthropologists in just this area. Kroeber, in a paper on the "History of Anthropological Thought," comments on the theorists — both biological (Huxley) and cultural (La Barre) — who are seeking new integrations between physical and cultural anthropology. Vogt, writing of "Anthropology in the Public Consciousness," analyses the attention given to anthropology in mass media of communication: national magazines, commercial and educational television, newspaper stories, paperback books, radio programs, and comic books and strips. In the period 1938-1940, five of fourteen anthropological articles appearing in national magazines were concerned with race and related topics; in 1952-54, only six articles of thirty-eight were on physical anthropological subjects. Physical anthropology has been well represented in television programs, and has "made" the newspapers when its stories were "hot" — as with the Piltdown hoax — but in other mass media has not fared as well.

In "Primatology in its Relation to Anthropology" Adolph Schultz surveys the current literature. He sees a growing interest in primatology and an increase of anthropologist's contributions to the field, although others have recently bemoaned the dearth of support for research in primatology.

Howells, in "Universality and Variation in Human Nature," discusses trends in the study of physical anthropology. The study of race has progressed from the "snuff and quill-pen stage" of mono- *versus* poly-genesis, through the "white coat and pince-nez stage" of typological efflorescence, to the contributions of the neo-typologists, the constitutionalists and the geneticists. The influence of the latter two groups have, he thinks, revolutionized physical anthropology — the former with its emphasis on the study of the individual as a whole rather than as a fractionated series of relatively unrelated, undigested dimensions; the latter with its emphasis on the breeding-group or population, and most recently with its contributions on the selective value of the several blood groups.

Loren Eiseley, in "Fossil Man and Human Evolution," is concerned with the evolution of the human brain, which, he suggests, evolved differently from the rest of man's body. He makes the assumption that, because man does many un-ape like things with his brain, the brains themselves are significantly different. Neurologists and neuro-anatomists would not support this view: the study of chimpanzee and human brains shows them to be much alike when compared with the brains of non-primates. Eiseley suggests that "later forms of paleanthropic man . . . vary little save in the degree of cranial advance throughout the latter half of Pleistocene times." This view, likewise, is not widely shared. He further states, "We have . . . stumbled into the world of essentially cultureless or almost cultureless proto-human types which are diverse in form because they represent evolution still at work *upon the parts of the body* (italics his), rather than upon the selection of mental patterns leading toward essential uniformity of other bodily characters." To this reviewer, there is no valid reason to assume that mind is in any way distinct from body or subject to any different mode of evolution. Despite the lack of direct evidence, one has little reason for disagreement with him when Eiseley further suggests that evolution has progressed in such a fashion as to " . . . bring everyone out on the same potential intellectual level . . ." and indicates that this has been brought about by " . . . some aspect of the environment which is selective and yet common to all men everywhere." He points to the social nature of man as this common feature. However, while man *is* the only cultural animal he is *not* the only social one and it seems difficult to explain man's uniqueness in

the animal world by putting the emphasis on man's sociality rather than on his culturality.

Seen as a whole this first Yearbook of Anthropology is a landmark in anthropological publishing. Although there may have been doubts at some times of the unity of physical anthropology with the rest of anthropology in the United States, that unity appears now to be fully established. One has only to read the contributions by the foreign scholars to realize that in their countries anthropology is more segmented than it is in the United States, and that we are now at least moving in the direction of the study of man as a unified discipline.

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BOOK NOTES

BONE AND JOINT X-RAY DIAGNOSIS. By M. Ritvo. 752 pp., 398 figs. Lea & Febiger, Philadelphia. 1955.

Deserving special notice of physical anthropologists is Ritvo's chapter I, "General Considerations," which includes terminology, methods, densities and interpretations of x-ray films; plus a section on osteology and factors influencing bone tissue changes. The remaining chapters are those expected; that is, heredity, congenital, developmental, traumatic infectious and endocrine-metabolic data. The volume contains a generous number of excellent x-ray plates in each section.

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THE LOWER PALAEOLITHIC SITE OF MARKKLEEBOERG AND OTHER COMPARABLE LOCALITIES NEAR LEIPZIG. By Rudolf Grahmann and edited by Hallam L. Movius, Jr. 509-687 pp. Trans. Am. Phil. Soc., Vol. 45, Pt. 6. 1955.

This monograph is a critical study of the collection of archeological material from Markkleeberg. In 75 excellent photographs or drawings, the tools (destroyed in World War II) are described in detail while the text deals with the geology, archeology and the significance of this important Lower Paleolithic site.

F.P.T.

FRENCH BIBLIOGRAPHICAL DIGEST: PHYSICAL ANTHROPOLOGY AND PREHISTORIC ARCHAEOLOGY. Part I, No. 15, Series II. The Cultural Division of the French Embassy, New York. 1956.

Books, theses, articles and other publications on physical anthropology and archeology appearing in the French literature since 1947 are listed in this bibliography.

F.P.T.

THE DIAGNOSIS AND TREATMENT OF POSTURAL DEFECTS. By W. M. Phelps, R. J. H. Kiphuth, and C. W. Goff. 2nd Edition, 190 pp. Charles C Thomas, Springfield. 1956.

This edition has added new data and concepts to those of the first which appeared in 1932. The first two chapters deal with the evolutionary background and environmental factors which influence human posture while the remainder of the book is directed to clinical considerations useful in the treatment of postural defects.

F.P.T.

SPACE REQUIREMENTS OF THE SEATED OPERATOR. Geometrical, Kinematic, and Mechanical Aspects of the Body with Special Reference to the Limbs. By Wilfred T. Dempster. 254 pp. WADC Technical Report 55-159. Wright Air Development Center, Ohio. 1955. (Copies obtainable from: ASTIA Document Service Center, Knott Building, Dayton 2, Ohio.)

This monograph represents applied physical anthropology and anatomy at its best. The problems of the sponsors are met, but in addition there is a feedback of basic data, concepts and techniques to the scientific disciplines. The description of this study is best given by a part of the author's abstract, which follows. "The structure of the limb joints and the range and type of their motions were studied on cadaver material, with supplementary work on living subjects, in order to clarify geometric, kinematic and engineering aspects of the limb mechanism." "Applications of the above information to analyses of horizontal push and pull forces in terms of couples permitted an evaluation of the effectiveness of body mass, leverages and support areas."

F.P.T.

BIBLIOGRAPHY ON SOUTHWESTERN ASIA: I, II, III. By Henry Field. I-106, II-126, III-230 pp. University of Miami Press, Coral Gables, Florida. I-1953, II-1955, III-1956.

These are summary bibliographies of references since 1940 dealing with Southwest Asia — from Suez to the eastern borders of Afghanistan. Part I covers the period from 1940-1952; Part II from 1953-1954 and Part III the year 1955. The references (about 13,000) are listed under numerous subject headings and Parts II and III include items previously overlooked.

F.P.T.

BODY-BUILD, BODY-FUNCTION, AND PERSONALITY. Bengt Lindegard, Editor. Lunds Universitets Arsskrift. N.F. Avd. 2. Bd 52. Nr 4-10, Lund, Sweden. 1956.

In this series of papers by Lindegard and others, the results of medical anthropological investigations on 320 healthy 20-year-old Swedish army men are given. Somatotypes, physical activity levels, steroid metabolism, fat distribution, endocrine levels and psychological features of these men are described and their interrelationships studied.

F.P.T.

OSNOVY ANTROPOLOGII. By Ia. Ia. Roginskii and M. G. Levin. 502 pp. University of Moscow. 1955. (In Russian.)

This is a basic anthropology text book dealing primarily with evolution, fossil man and the modern races of the world. The data on the Russian people and archeological material is of special interest but in all other respects it appears quite conventional.

F.P.T.

A STUDY OF THE CRANIAL AND SKELETAL MATERIAL EXCAVATED AT NIPPUR. By Daris Ray Swindler. 40 pp., 8 plates, 42 tables. \$.75. Museum Monographs. The University Museum, Philadelphia. 1956.

In this short monograph the measurements and statistical analyses are given which are derived from 57 crania and numerous long bones from Nippur. Swindler concludes that these were a long headed Mediterranean type much like many found in Mesopotamia today.

F.P.T.

MAN, CULTURE, AND SOCIETY. Harry L. Shapiro, Editor. 380 pp., 13 plates, 16 figs. \$5.50. Oxford University Press, New York. 1956.

Professor Shapiro has organized this book to be an introduction to anthropology for the general reader. He has brought together the essays of 17 authors in 16 related chapters dealing with man and society. Shapiro writes the chapter on human origins while Griffin, Movius, Childe, Brew and Cressman deal with prehistory in the New and Old Worlds. The remainder of the book is concerned with culture and society.

F.P.T.

MAN'S ROLE IN CHANGING THE FACE OF THE EARTH.

William L. Thomas, Jr., Editor, with collaboration of Carl O. Sauer, Marston Bates, and Lewis Mumford. 1193 pp., 180 illus., 33 tables. \$12.50. University of Chicago Press. 1956.

Here are published 53 background papers and summaries of discussions at the Wenner-Gren Foundation's symposium on "Man's Role in Changing the Face of the Earth" held June 16-22, 1955. This very large volume combines the points of view of several disciplines when considering the effects of human activity, and includes extensive bibliography, illustrations and numerous data. No summary of such a volume can do justice to it — only a reading.

F.P.T.

ON THE EVIDENCE OF RANDOM GENETIC DRIFT IN HUMAN POPULATIONS ¹

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INTRODUCTION

The name of Sewall Wright is invariably, inevitably associated with the concept of genetic drift. Genetic drift is even commonly referred to as the "Sewall Wright effect." This is the more surprising when a careful study must indicate that Sewall Wright himself has scarcely ever used the phrase and at no time has indicated it to be an evolutionary factor of decisive significance. Wright's own term of preference is "random genetic drift," which more explicitly labels the nature of the factor than does the commonly used phrase.

Wright ('49a, b; '50, 51a) has classified the modes of change in gene frequency into three categories, (1) those resulting from systematic pressures (recurrent mutation, intrapopulation selection, and recurrent immigration and crossbreeding), (2) those resulting from fluctuations in the systematic pressures or from random accidents of sampling, and (3) those resulting from unique events, such as a mutation favorable at its first occurrence, a unique selective event or hybridization, swamping by mass immigration, or a unique reduction in numbers. Among these, it is the fluctuations in gene frequencies due to accidents of sampling in meiosis and fertilization that are properly called random genetic drift whenever they become compounded over successive generations into wide departures from the original equi-

¹ This paper was given as a part of a symposium organized in honor of Sewall Wright by the Biometric Society, the Genetics Society of America, and the American Society of Human Genetics and held at the A.I.B.S. meetings in East Lansing, Michigan, on September 6, 1955.

librium. The alterations of gene frequency produced by unique events have often been included in the concept of genetic drift because they too represent accidents of sampling, in a sense, in particular such events as a unique reduction in numbers, which like genetic drift is closely related to the evolutionary effect of the size of population.

No one would question that accidents in sampling the gene pool of a parental generation must occur in the formation of the gene pool in the offspring generation; or that the magnitude of these deviations from expectation varies inversely with the size of the gene pool, or with N , the effective size of the population. The rather acrimonious controversy that has marked discussions of genetic drift in the past seems to be based not on a genuine difference of opinion in this respect, but rather upon a persistent failure of the opponents of genetic drift to recognize it as a significant element in the interplay of evolutionary forces. Wright's views, properly represented, stress the great significance of intergroup selection in relatively large populations subdivided into locally differentiated subgroups. Both the effectiveness of isolation of the subgroups and their effective population sizes are important to the amount of local differentiation that can occur. Although Wright agrees that "fluctuations in gene frequencies in small completely isolated communities rarely if ever contribute to evolutionary advance, but merely to trivial differentiation, or in extreme cases to degeneration and extinction" (Wright, '51b), this is not to deny that random genetic drift tends to oppose the direction of selection in such populations, and may either overwhelm it (whenever s is less than $\frac{1}{2N}$) or modify it (whenever s is greater than $\frac{1}{2N}$). The outcome is simply determined by the relative magnitudes of the interacting evolutionary factors. It is in principle unsound to ignore random genetic drift as being negligible in effect except when it can be demonstrated that the magnitude of selection and the size of population are such as to make it negligible. Even when the size of population is quite accurately known, and when it seems obvious that

selection is favoring the spread of one allele and the restriction of its competitor or competitors, as in the case of the medionigra allele in the moth *Panaxia dominula* L. studied so fully by Fisher and Ford ('47) and by Sheppard ('53), it still does not follow that none of the change in gene frequencies at the locus studied is attributable to random accidents of sampling. Nor does it follow that at other loci in the same population, where the selection pressure between competing alleles is lower, genetic drift may not be the predominant factor in establishing the local frequencies of the alleles.

*The demonstration of genetic drift by
age-group analysis*

The literature on blood group frequencies is full of pronounced deviations occurring in small, genetically rather isolated groups. A previous study (Glass et al., '50) dealt with a group where it may be assumed more plausibly than in most situations that the environmental, selective conditions acting upon the isolate are identical with those in the main population within which the isolate exists. This was the study of gene frequencies in a community of Dunkers living in Franklin County, Pennsylvania, on farms and in small towns intermingled with the general population. The evidence presented indicated a striking difference in gene frequencies at the ABO locus, at the MN locus, and in respect to certain other physical traits of no known or obvious selective significance. It may, however, be objected that in these instances one cannot distinguish the random genetic drift over a succession of generations from the effect of a unique sampling that provided a very few genotypes in the progenitors of the isolate.

Probably the most satisfactory demonstration of genetic drift that can be made is to show that in successive generations of an isolate which shares a common environment with a large population within which the analyzed gene frequencies are quite stable, the gene frequencies in the isolate on the contrary are shifting in such a way that although no two successive

generations manifest a statistically significant difference, the cumulated shift over several generations possesses statistical significance. This may be done by the method I have elsewhere (Glass, '54) called "age-group analysis," which has now been applied to the data obtained from the Dunker community in Franklin County, Pennsylvania.

TABLE 1
Franklin County (Pa.) Dunkers — Age-group analysis

I. ABO blood groups — phenotypes								
	O		A		B		AB	TOTAL
	No.	%	No.	%	No.	%	No.	
Gen. 1	16		26		2		0	44
		36.4		59.0	4.6			
Gen. 2	34		47		2		3	86
		39.6		54.6	5.8			
Gen. 3	31		62		3		2	98
		31.6		63.3	5.1			
χ^2_3 Gen. 1 and 2	0.27		.975 > P > .95				N =	228
χ^2_3 Gen. 2 and 3	1.40		.80 > P > .70					
χ^2_3 Gen. 1 and 3	0.29		.975 > P > .95					
χ^2_6 Gen. 1, 2, and 3	1.50		.975 > P > .95					
II. A, B, and O gene frequencies								
	A		B		O		TOTAL	
	No.	f.	No.	f.	No.	f.		
Gen. 1	32.5	.370	3.2	.036	52.3	.594	88	
Gen. 2	59.6	.347	2.6	.015	109.8	.638	172	
Gen. 3	81.0	.413	4.9	.025	110.0	.562	196	
$\chi^2_4 = 3.32$		.70 > P > .50					N = 456	

Table 1 gives the analysis with respect to the ABO blood group frequencies. It is obvious that there occurred no significant shift in these frequencies over the period of the three now-living generations, aged 1-27 years, 28-55 years, and 56 years of age or older. Consequently the highly significant difference between the ABO frequencies of the Dunkers and the general U. S. White population, which

transcends the range between the W. German population from which the Dunkers originally came and the major population within which they now live, must be attributed to some shift in gene frequencies that occurred more than three generations ago — perhaps to the unique sampling effect that occurred when the 27 Dunker families first came to

TABLE 2

Franklin County (Pa.) Dunkers — Age-group analysis

I. MN blood groups — phenotypes

	M		MN		N		TOTAL
	No.	%	No.	%	No.	%	
Gen. 1	12	28.6	22	52.4	8	19.0	42
Gen. 2	34	44.8	32	42.1	10	13.1	76
Gen. 3	48	55.8	30	34.9	8	9.3	86
χ^2 Gen. 1 and 2 = 2.98			.30 > P > .20		N = 204		
χ^2 Gen. 2 and 3 = 2.00			.50 > P > .30				
χ^2 Gen. 1 and 3 = 9.50			.01 > P > .005				

II. M and N gene frequencies

	M		N		TOTAL
	No.	f.	No.	f.	
Gen. 1	46		38		84
		.550		.450	
Gen. 2	100		52		152
		.685		.342	
Gen. 3	126		46		172
		.735		.265	
χ^2 Gen. 1 and 2 = 2.90			.10 > P > .05		N = 408
χ^2 Gen. 2 and 3 = 2.11			P > .10		
χ^2 Gen. 1 and 3 = 8.55			.005 > P > .001		
χ^2 Gen. 1, 2, 3 = 8.83			.02 > P > .01		

North America in the early 18th century, or to another unique sampling effect that occurred when the Dunkers split away from the more numerous and less strict branches of the sect, in 1881; or possibly to genetic drift that occurred more gradually during some portion of the intervening time.

Table 2 presents the analysis for the MN blood group frequencies. Whether the analysis is carried out on the basis

of the phenotypic frequencies (table 2, I) or on the basis of the gene frequencies (table 2, II), it is clear that although neither the shift between the first and second generations, nor the shift between the second and third generations, is significant, yet the continuation of the shift in the same direction over two generations leads to a significant difference between the first and third generations.

TABLE 3
Franklin County (Pa.) Dunkers — Rh blood types

	R_1R_2		R_1		R_2		rh		R_0		TOTAL
	No.	%	No.	%	No.	%	No.	%	No.	%	
Gen. 1	5	11.9	23	54.8	10	23.8	4	9.5	..		42
Gen. 2	16	21.1	39	51.4	11	14.5	9	11.8	1	1.3	76
Gen. 3	9	10.5	55	64.0	15	17.4	7	8.1	..		86
$\chi^2_s = 6.42$ $.50 > P > .30$ $N = 204$ $(R_0 \text{ neglected}).$											

TABLE 4
Franklin County (Pa.) Dunkers — Handedness

	L	LR	R	TOTAL	% R.
Gen. 1	1	0	43	44	97.7
Gen. 2	2	0	80	82	97.6
Gen. 3	12	2	95	109	87.2
$\underbrace{\hspace{1.5cm}}_{7.2\%}$			92.8%	$N = 235$	

$$\chi^2_1 \left\{ \begin{array}{l} \text{Gen. 1 + 2 vs. 3} \\ \text{L + LR vs. R} \end{array} \right\} = 7.97 \quad .005 > P > .001$$

(Yates corr.)

Table 3 shows that for the Rh blood types there is no statistically significant drift, although the frequencies of R_1R_2 (CDE) and R_2 (cDE) phenotypes alter so erratically that had the population been slightly larger they would be so. In this case the trend in the second generation reversed the direction of the trend occurring in the first generation.

Table 4, the analysis of the frequencies of left and right handedness, offers yet another type of shift in gene frequencies. The first and second generations are virtually identical in their frequencies, whereas the third generation departs

widely from the second, and very significantly from the frequencies of the first and second generations combined. It is well at this moment to sound a note of warning. Conceivably the shifts in the frequency of a genetic trait in different generations, *if sampled at different ages*, might be due to differential mortality, or to a late, varying age of onset, or to modification of the trait by environmental pressures. In the present instance, although I would not care to suggest that righthanded people tend to outlive lefthanded ones, I think that there may well have been a greater degree of family and social pressure to transform lefthanded children into right in former generations than now. Parenthetically, it may be pointed out that, taken at face value, these data would appear to exclude Rife's ('51) hypothesis that ambidexterity is the heterozygous condition of a monofactorial genetic difference. But of course the diagnostic criteria in the present study may not be those used by Rife, and in fact are based solely on the statements of the subjects themselves.

Table 5 gives the age-group analyses for 5 other physical traits, for which the modes of inheritance have not been fully worked out. Although as a whole, middigital hair patterns fail to show a statistically significant difference between generations, there are certainly some striking alterations of frequency, especially in classes 1 and 3. The type of ear lobes was remarkably consistent from generation to generation; and the same may be said of the frequency of distal hyperextensibility of the thumbs. But length of the 5th digit in comparison with the 4th, and the presence of a median upper diastema between the incisor teeth showed more variation, although in the latter case only at the border of statistical significance. In the case of the length of the 5th digit, the same kind of shift appears as showed up in regard to handedness; the first and second generations are alike, but the third generation is quite different.

In short, over the interval of three generations some genetic loci in the Dunker population exhibit random genetic drift, some remain stable, some shift and return, and some shift

TABLE 5
Franklin County (Pa.) Dunkers—Age group analysis

I. Mid-digital hair patterns

	CLASSES										TOTAL
	0		1		2		3		4		
	No.	%	No.	%	No.	%	No.	%	No.	%	
Gen. 1	25	58.2	3 ¹	7.0	4	9.3	9 ¹	20.9	2	4.6	43
Gen. 2	42	51.9	19	23.4	6	7.4	11	13.6	3	3.7	81
Gen. 3	56	57.1	21	21.4	12	12.25	9 ¹	9.2	0	..	98
							combined				

combined

$$\chi^2_6 \text{ (Classes 3 and 4 combined)} = 11.18 \quad .10 > P > .05. \quad N = 222$$

¹ Highest contributions to χ^2 .

II. Ear lobes

	LOBED	NON-LOBED	TOTAL	% NON-L
Gen. 1	10	38	48	79.1
Gen. 2	22	57	79	72.1
Gen. 3	27	84	111	74.7

$$N = 238$$

$$\chi^2_2 = 0.88$$

$$.70 > P > .50$$

III. Distal hyperextensibility of the thumb

	-	+	TOTAL	% DHT
Gen. 1	23	3	26	11.5
Gen. 2	39	5	44	11.4
Gen. 3	45	8	53	15.0

$$N = 123$$

$$\chi^2_1 \text{ (Gen. 1 + 2 vs. 3)} = 0.36$$

$$.70 > P > .50$$

IV. Length of 5th digit¹

	+	=		-		TOTAL
	No.	No.	%	No.	%	
Gen. 1	5	35	73.0	8	16.7	48
Gen. 2	5	62	76.6	14	17.3	81
Gen. 3	0	76	69.0	34	31.0	110

$$\chi^2_2 \text{ (Gen. 1 + 2 vs. 3)} = 13.65$$

$$\chi^2_1 \text{ (Same ignoring + class)} = 5.14$$

$$.005 > P > .001$$

$$.025 > P > .01$$

$$N = 239$$

¹ + Indicates 5th digit longer than joint between middle and distal segments of 4th digit (distal joint).

— Indicates 5th digit shorter than distal joint.

= Indicates 5th digit extending to distal joint.

V. Median upper diastema

	+	-	TOTAL	% +
Gen. 1	41	2	43	95.4
Gen. 2	67	7	74	90.5
Gen. 3	86	20	106	81.1

$$N = 223$$

$$\chi^2_1 \text{ (Gen. 1 and 3)} = 3.77$$

(Yates corr.)

$$.10 > P > .05$$

$$\chi^2_2 \text{ (Gen. 1, 2, 3)} = 6.70$$

$$.05 > P > .025$$

at one time but not at another. The picture is much as would be expected in a small genetic isolate ($N=90$) where the vectorial evolutionary forces, and especially selection, are sometimes overwhelmed by the random scattering effect of the sampling process. It may be pointed out that even though the gene flow into the isolate was estimated as amounting to 10–15% per generation, that is still in absolute numbers so small a supply of genes from the main population that it could scarcely be a representative sample of the surrounding gene pool, but must itself be subject to the vagaries of small samples.

That no such exaggerated fluctuations appear in successive generations of large populations is demonstrable for some of the same genetic characteristics. Boorman ('50) has shown how very similar the ABO and Rh frequencies are in 2,000 consecutive London mothers and their 2,000 infants; and Bryce et al. ('50) have found the same consistency in the ABO frequencies of 7,856 Australian mother-infant pairs, 23,583 blood donors, and 176,943 members of the defense forces. This constancy, in fact, existed in spite of the statistically significant excesses or deficiencies of certain types of infants born to mothers of a given blood group. It is, consequently, clear that the extreme fluctuations of gene frequencies in the Dunker community over the three generations studied are attributable to random genetic drift.

The interplay of genetic drift and selection

In the long run we must expect evolution, insofar as it is adaptive, to be determined by selection. Random genetic drift can scarcely do more than heighten the store of genetic variability present in local differentiated populations upon which intergroup selection may act. That such variability may likewise exist when a trait is obviously subject to strong selection may be illustrated by the frequencies of the sickle-cell trait in various African tribes. Foy et al. ('54, '55), among others, have published such data, showing not only great

variations in the frequency of sickling, as well as in the ABO frequencies, among different tribes, but even "in subgroups within the same tribe, although such subgroups speak the same language, have the same cultural and social characteristics, and now intermarry freely." It seems that this case affords another example of the interplay of genetic drift and selection, although it may be impossible in dealing with a historical situation ever to analyze it completely and satisfactorily.

No one has more clearly perceived the necessity of dealing with the interplay between genetic drift and selective forces in analyzing actual gene frequency situations than Alice M. Brues ('54). In a strikingly original analysis she has utilized the very existence of the randomizing effect of genetic drift to postulate the magnitudes and directions of the several selective forces which act upon the human ABO blood group frequencies in such a way that, instead of all possible combinations of frequencies being realized, only a limited, rather small range of frequencies of *A*, *B*, and *O* in actuality occurs. She notes that "the effects of genetic drift are strongly evident in respect to the A-B-O gene frequencies within populations otherwise distinct and relatively homogeneous," e.g., the North American Indians, Pre-Dravidians of India, Eskimos, Polynesians, Australian, and Ainu. The range of *A* frequencies within these otherwise quite homogeneous groups is half or more than half of the total world range—in fact, the North American Indians bracket the entire world range—and it appears quite impossible to account for such differences on the basis of group intermixture and hybridization, or of selection based on differences in environment. Indeed, "the evidence for the vigor of genetic drift under more primitive conditions is so convincing as to be disturbing. If it has acted so strongly even after the formation of certain races and subraces as we now know them, why has it not produced, during the whole period of the differentiation of the species, often under conditions of isolation and smallness of numbers more marked than have existed subsequently,

a range of variation much greater than we now see?" Only the differential action of selection on A , B , and O seems adequate to explain the restriction of the frequencies, since the time in generations since these alleles originated is clearly far more than enough to have permitted complete randomization in the absence of selection pressures. The supposed non-adaptive nature of the various blood group systems can then be dismissed as a fiction, even were there no independent evidence of differential fertility, maternal-fetal incompatibility, and the like.

[Possibly a system of mutation pressures could be devised that would bring about the same frequency distribution of the ABO alleles as actually exists, and Miss Brues has ignored this possibility. However, at present we know nothing about the mutation rates of the ABO alleles, and can do no better than interpret the analysis in terms of selection and/or mutation pressures.]

The fact that the $A-B-O$ frequency distribution for all populations is restricted and has a single center implies, as Miss Brues points out, that heterozygotes are in general more favored than homozygotes. It proved possible to arrive at a satisfactory mathematical model to explain the existing family of ABO gene frequencies by postulating a 25% loss of OA heterozygotes through maternal-fetal incompatibility, and selection pressures of 0.0% for OO , +15% for OA , +5% for OB , -6% for AA , +3% for AB , and -4% for BB . This vectorial system focuses upon the point at which the respective frequencies of A , B , and O are 25%, 15%, and 60%, the vectors being very small near the focus and larger and larger as distance from the focus increases. Miss Brues points out that "any such vector system . . . will be always interacting with genetic drift. Small or isolated populations will be continually scattering as the result of drift, but in more copious populations . . . genetic drift will be quite ineffective, and selective pressures will act with great constancy. All such populous groups should then tend inexorably to move toward the final equilibrium point. . . . Most . . .

major population groups, White, Mongoloid, and Negro alike [have] very low vectors. . . . The primitive condition of wide random range of blood group frequencies is not too far in the past to account for the diversities of the now more populous groups, even though constant selective factors may have been standardizing blood group frequencies since population levels increased." This is indeed a refreshing approach in contrast to that overemphasis either on genetic drift or on selection which has so characterized the "genetic drift controversy," and which cannot fail to remind one of the sterile "heredity or environment" controversies of an earlier period. Miss Brues provides a very apt analogy in likening the interaction of genetic drift and selection to the respective effects of Brownian movement and gravity on suspended particles of different sizes. Would anyone suppose that because gravity acts on suspended particles the effects of Brownian movement are inconsequential? That depends on the size of the particle.

Genetic drift as an evolutionary factor

It remains to consider whether the variety of gene frequencies established in small populations by random genetic drift may subsequently have any significant role in evolutionary processes. I have previously suggested (Glass, '54) that in the human species "explosive increases in population size, such as took place with the advent of agriculture, might allow the particular genetic characteristics of one isolate to become stamped upon a population too large to be swamped when absorbing smaller groups." That idea has been attractive to many anthropologists. Brues ('54) likewise agrees, saying, "Later increase in size will not reverse any peculiarities acquired while a group is small." But evidence to support this view is not forthcoming at present from the field of human population genetics. Instead, we must appeal to the *Drosophila* geneticist. In studying the selective action of exposure to DDT upon fruitflies, King ('55) found that

each of two selected lines developed its own unique integrated polygenic system. I am permitted by his kindness to quote from a paper still in press and to discuss the implications of these experiments in his own words. "The fact that each of two selected lines developed its own integrated polygenic system within a dozen generations leads one to suspect that there are more than two such systems possible, probably many. Wallace and King ('51, '52) discovered in their work with irradiated and control populations that a closed population very rapidly develops a uniquely integrated genetic system which then tends to persist. Very probably this is what happened in each selected line. The manner in which a line could respond to selection was to some extent determined by the genetic nature of the sample from which it was started, and, having started along one certain road, it kept on. The inevitable sampling error which occurs when a line is taken from a larger population is very likely the *anlage* of the genetic individuality of the line. This is, of course, an example of the principle of random genetic drift, and its operation can easily be envisaged without insisting that sampling error can outweigh selection either in general or in a single generation in a going population. All that is necessary is for the new population to be denied access to the larger gene pool of which it was formerly a part.

"We obtain here, I believe, some insight into the nature of the creative aspect of evolution. Every species has within it potentialities for adaptive radiation so vast that no finite population can actualize them all. As long as the population remains a substantially panmictic unit, the random ebb and flow of genes will result in a variability maintained within limits determined by the adaptive norm. When a sample from the larger population is shut off from the whole, the degree to which and the manner in which the frequencies within its gene pool depart from those prevailing in the larger unit exclude some potentialities entirely and by this very fact increase the probability that others will be actualized. Whenever a new closed population is set up, a gamble is taken

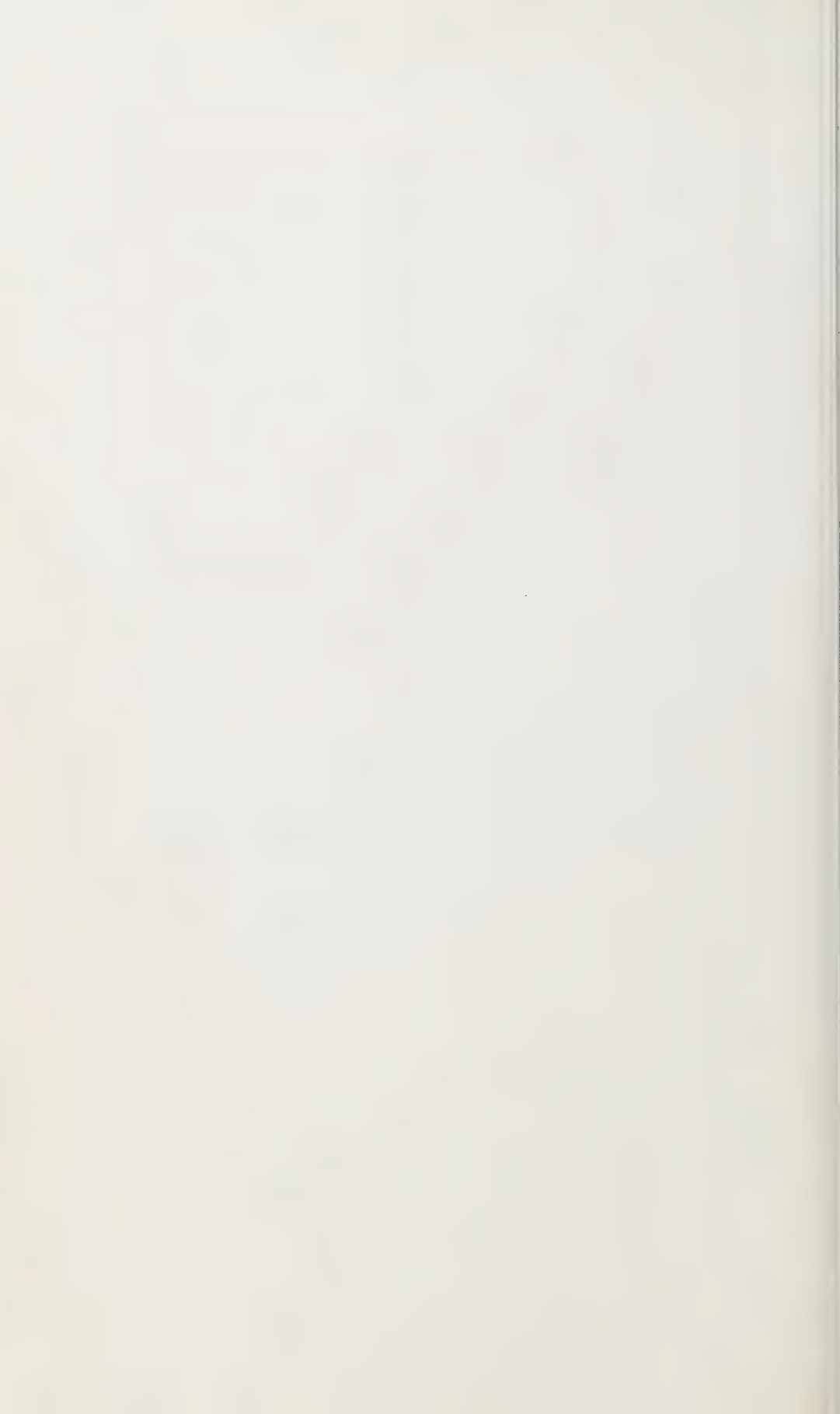
which may result in nothing of consequence or which may engender a strikingly new creation."

In this way, then, we may picture the creative role of random genetic drift. Like the randomness of mutation, which produces a hundred or a thousand deleterious genes to one that aids the organism in its struggle for survival, genetic drift may establish a hundred or a thousand deleterious mutations, fated eventually to be eliminated, before it aids materially in the initial establishment of a mutation of value. And, like recombination — indeed, through recombination — genetic drift provides those unique genotypes that characterize small closed populations, and upon which selection can act with so much richer a variety of outcome than when it is limited in material to the phenotypic uniformity of the large, panmictic population. In Sewall Wright's own picturesque imagery, the way from one adaptive peak to another leads through the valley. The shadow of selection broods darkly over the evolutionary way, and only the strong or the fortunate escape, only those forearmed against the exigencies they meet. Stabilizing selection adapts more perfectly only to those conditions that have existed up to now. It may be that solely among the less highly adapted, small isolated populations there will occur the genotypic system that fits the new conditions. In helping to create a diversity of such systems, random genetic drift plays its part.

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DIMENSIONAL CHANGES IN THE HUMAN HEAD AND FACE IN THE THIRD DECADE OF LIFE

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FOUR FIGURES

INTRODUCTION

The study here reported is designed to analyze size changes taking place in the human head and face during the third decade of life. The nature of dimensional change in six anthropometric measurements is assessed by fitting curves mathematically to data on white male and female military personnel.

Quantitative changes in the size of head and face in the early adult period have not been investigated intensively, though the data of child growth studies, as well as the findings of age change studies on adults, suggest that certain dimensions of head and face increase in size after adolescence. Investigations of child growth are often terminated before the growth curves of the subjects in some dimensions have reached a plateau. Thus Dearborn, Rothney, and Shuttleworth ('38), reporting longitudinal material from the Third Harvard Growth Study, list increments in the length and breadth dimensions of the head through the terminal group studied at 20 years of age. Similarly, the analysis by Simmons ('44) of data from the Brush Foundation Study concerns the growth of children through the first 17 years of life. At the final age studied, head length and breadth had not attained terminal size.

Studies pertaining to age changes in the adult have been designed chiefly to survey the total age range from early

adulthood through senescence. Consequently, the data reported are often grouped into large age classes, and the analyses are directed toward contrasting mean size differences between younger and older age groups or describing general size trends.

Hellman ('27) concluded, on the basis of his analysis of American Indian crania, that the face continues to grow in height and width to "old age," with a subsequent diminution in size during senescence. Skulls were considered to represent individuals of old age when Hellman's stage VI of dental development had been attained, i.e., when the grooves on the occlusal surfaces of the molar teeth were worn off.

Hrdlička ('36) summarized the data of Parchappe (on adult French), Pfitzner (on adult Alsations), Jarcho (on Russians, Kirghiz, Uzbeks, and Armenians), as well as his own data on "Old American" whites and American Indians, in support of his contention that the length and breadth of head and face increase until at least the fourth, and possibly the sixth, decade of life. Büchi ('50) investigated the problem of age change by remeasuring a series of adult Swiss males and females after a lapse of nine years. His data, grouped in intervals of nine years, show dimensional increases occurring in the diameter of head and face of both sexes well into the sixth decade of life. Hooton and Dupertuis ('51) reported anthropometric data on approximately 10,000 Irish males, in class intervals of five years. Here, again, inspection of the mean values for successive age groups revealed increases in head circumference, head length, and bizygomatic diameter through 35-39 years, and increases for head breadth and total face height through 30-34 years.

The findings of a recent study by Lasker ('53) of dimensional changes with age in two adult Mexican series do not fully corroborate those of earlier investigations. In head length, Lasker found little tendency toward change in males; in females, he found an increase with age in only one of the two series. In total face height, he found an increase with age in males of one series; in females, he found an increase

with age in both series. In head breadth and bizygomatic diameter he found a tendency to increase with age in both sexes in both series.

The data in the literature provide no uniform conclusions or even consensus concerning the ages at which increase in each diameter of the head and face ceases. The present study attempts to pick up the growth curves where they are dropped by child growth studies and to investigate their trend through the early adult period.

MATERIALS AND METHODS

The data used in this study are drawn from material collected in 1946 by the Army Anthropometric Survey, Office of the Quartermaster General. The male series comprises a population of 5,688 white, third-generation Americans (all four grandparents born in the United States) measured at Fort George G. Meade, Maryland, under the writer's supervision. The female series consists of the total survey population of 7,420 white WACs and Army nurses, native born, but not necessarily having all four grandparents American born. Both series were measured at the time of separation from military service. The age range was from 19 through 33 years.

The dimensions selected for study were: head length, head breadth, head circumference, total face height, bizygomatic diameter, and nose height. In the female series only total face height is reported. The techniques of measurement have been described by Randall and Baer ('47). The distribution of subjects by age and sex and the mean values for the dimensions at each age are given in table 1. The ages shown represent the lower limit of each class interval, since age was recorded as of the subject's last birthday.

The curve for each dimension was fitted by the method of orthogonal polynomials described by Snedecor ('46). This method permits the fitting of terms of successively higher degree to the data and the testing of each term for significance. The curve resulting from the plotting of the first-degree term

TABLE 1
Mean values (mm)¹ of six dimensions of the head and face by age
 American white military personnel

AGE IN YEARS	NUMBER	M A L E S										F E M A L E S			
		HEAD LENGTH		HEAD BREADTH		HEAD CIRCUMFERENCE		FACE HEIGHT		BIZYGOMATIC DIAMETER		NOSE HEIGHT		FACE HEIGHT	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
19	475	194.59	.30	151.27	.24	56.65	.07	123.50	.32	138.53	.22	53.20	.20	108.06	...
20	467	194.37	.32	151.47	.25	56.70	.07	124.48	.32	138.37	.23	54.13	.20	110.12	1.31
21	543	194.80	.27	151.37	.22	56.65	.07	124.95	.30	138.72	.22	54.40	.19	110.56	.37
22	402	195.02	.33	151.52	.26	56.76	.07	125.31	.34	138.70	.23	54.25	.22	111.54	.24
23	393	194.78	.33	151.61	.26	56.73	.08	124.99	.35	138.67	.27	54.25	.21	111.00	.19
24	332	195.20	.36	151.42	.28	56.76	.08	126.21	.39	138.89	.28	54.78	.25	111.50	.21
25	403	195.07	.33	151.95	.27	56.79	.08	126.51	.35	139.32	.25	54.96	.21	111.38	.25
26	423	194.79	.32	151.31	.27	56.70	.08	126.45	.33	139.16	.25	55.20	.19	111.10	.28
27	335	195.14	.33	152.07	.31	56.87	.08	126.78	.34	139.54	.29	55.26	.24	111.94	.33
28	421	195.31	.31	152.00	.24	56.87	.07	126.94	.33	139.55	.23	55.37	.22	111.40	.38
29	487	195.26	.29	151.77	.23	56.87	.07	127.37	.32	139.29	.24	55.31	.20	111.32	.40
30	491	194.84	.29	152.14	.25	56.78	.07	127.47	.32	139.84	.24	55.48	.20	111.20	.46
31	274	194.98	.39	151.81	.31	56.68	.09	127.69	.42	139.68	.32	55.64	.25	112.34	.47
32	138	195.66	.59	151.54	.45	56.88	.14	127.79	.58	139.12	.51	56.04	.35	111.36	.57
33	104	194.69	.60	151.91	.51	56.70	.15	127.57	.68	140.29	.62	55.21	.48	112.06	.50

¹ Head circumference in centimeters.

comprises a straight line, while the second-degree term forms a parabolic arc. The "F" values obtained by fitting the first- and second-degree terms to the data for the six dimensions studied, and the level of significance of each term tested, are shown in table 2. While Snedecor used the method of orthogonal polynomials for fitting straight and curvilinear regression lines to individual observations, it can also be used to analyze the trend in a series of means. As Lindquist ('47)

TABLE 2

"F" values and levels of significance (p) for polynomials of six dimensions of the head and face

American white military personnel

DIMENSION	FIRST-DEGREE TERM*		SECOND-DEGREE TERM†	
	F	p	F	p
MALES				
Face height	143.90	.001	20.80	.001
Nose height	57.07	.001	9.21	.02
Bizygomatic diameter	42.34	.001	0.16	..
Head breadth	8.28	.02	1.71	..
Head length	4.52	.06	...	...
Head circumference	3.53	.10	...	...
FEMALES				
Face height	10.68	.01	1.21	..

Degrees of freedom: Males: *1 and 13; †1 and 12.
Females: *1 and 12; †1 and 11.

points out, however, application of this technique to mean data does not provide a test of adequacy of fit based upon within-group variance. Accordingly, the test of analysis of variance was used to determine the appropriateness of fitting curves other than a horizontal straight line to the data. Table 3 shows the "F" values and the findings on levels of significance from a test of the null hypothesis that the six dimensions under consideration are unaffected by age and that the population means comprise horizontal straight lines.

FINDINGS

Male series

The data given in tables 2 and 3 indicate that during the third decade of life the three facial dimensions of the male increase in size, while the three head dimensions do not change significantly.

TABLE 3

Analysis of variance for six dimensions of the head and face

American white military personnel

DIMENSION	SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	ESTIMATE OF VARIANCE	
MALES					
Face height	Between groups	9450.231	14	675.0165	F = 14.089
	Within groups	271759.309	5672	47.9124	p < .001
Nose height	Between groups	699.222	14	49.9444	F = 10.582
	Within groups	26707.858	5659	4.7195	p < .001
Bizygomatic diameter	Between groups	1326.672	14	94.7623	F = 3.575
	Within groups	150041.528	5661	26.5044	p < .001
Head breadth	Between groups	487.848	14	34.8463	F = 1.246
	Within groups	158447.962	5665	27.9696	p > .20
Head circumference	Between groups	34.983	14	2.4988	F = 1.057
	Within groups	13402.601	5668	2.3646	p > .20
Head length	Between groups	472.857	14	33.7755	F = *
	Within groups	238200.643	5664	42.0552	p *
FEMALES					
Face height	Between groups	263.678	13	20.2829	F = 1.562
	Within groups	96068.226	7397	12.9875	p < .10

* Within-group variance greater than between-group variance.

A first-degree term comprises a better fit of the mean data for face height, nose height, and bizygomatic diameter than does a horizontal straight line at the .001 level of significance. Correspondingly, the test of analysis of variance reveals that the between-group variance of the three facial dimensions is significantly greater ($p = .001$) than the within-group variance.

Further testing of the facial dimensions to determine the best fitting curves reveals that a second-degree term results in an improved fit of face height ($p = .001$) and nose height ($p = .02$), but is not applicable to bizygomatic diameter. The calculated curves and the mean values at each age for the three facial dimensions are shown in figure 1.

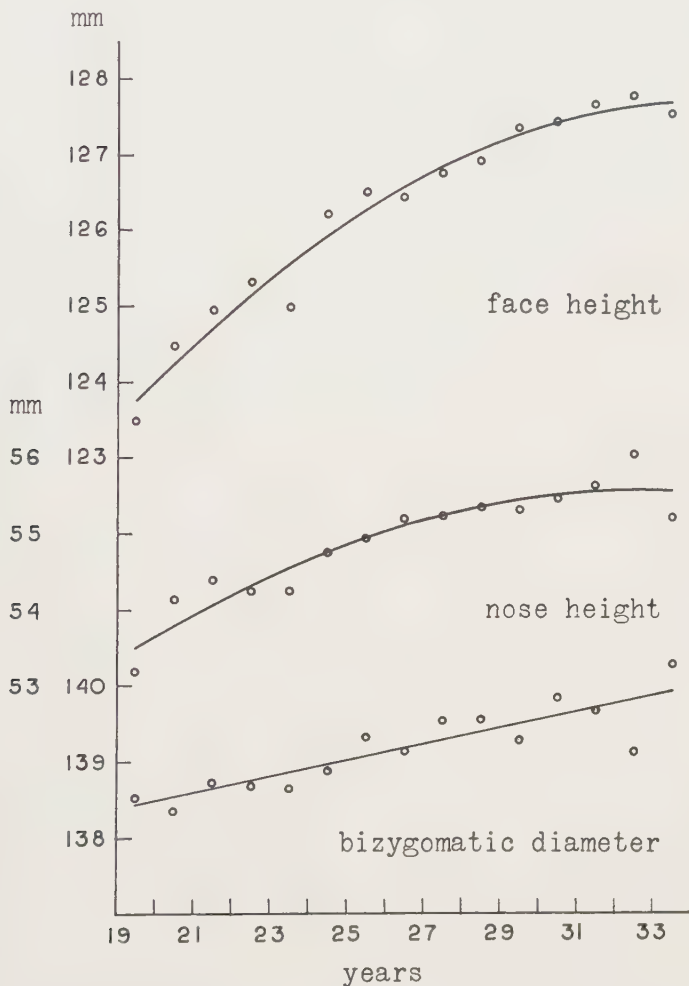


Fig. 1 Mean age values for face height, nose height, and bizygomatic diameter of U. S. Army white males from 19 through 33 years, plotted from data listed in table 1. Solid line represents a second-degree curve for face height and nose height and a first-degree curve for bizygomatic diameter.

In summary, face height and nose height exhibit a curvilinear pattern of slow deceleration, while bizygomatic diameter is characterized by slow linear increase.

Concerning the three dimensions of the head proper, testing of the significance of fit of the first-degree term shows the

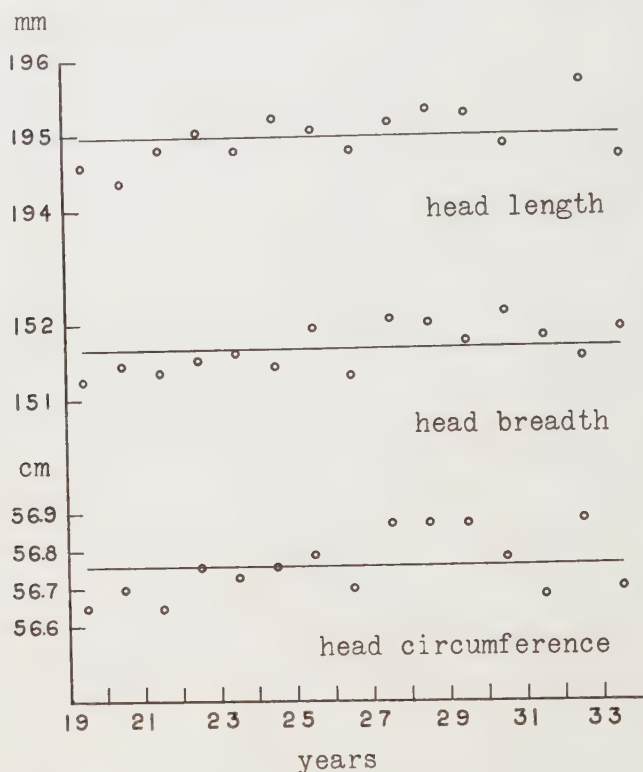


Fig. 2 Mean age values for head length, head breadth, and head circumference of U. S. Army white males from 19 through 33 years, plotted from data listed in table 1. The data for each of the three dimensions are shown fitted with a horizontal straight line, representing the mean of the 15 yearly values.

following levels of probability: head breadth, $p = .02$; head length, $p = .06$; head circumference, $p = .10$. However, the inappropriateness of a first-degree term, or any curve other than a horizontal straight line, as applied to these data is indicated by the estimates of variance.

For head breadth and head circumference the between-group variance is not significantly greater than the within-group variance (p greater than .20); while for head length the within-group variance is actually greater than the between-group variance (table 3). The mean values at each age for the three head dimensions are plotted in figure 2. A horizontal straight line, representing simply the average of the 15 means for each dimension, has been fitted to the data.

*Proportional relationships of the segments
of male face height*

Some investigators of craniofacial growth by roentgenography comment upon the constancy of facial proportions during various phases of occlusal development. Broadbent ('41) found that a proportional increase in the size of the segments of the face occurs after the deciduous dentition is completed. Brodie ('41, p. 259) in discussing the growth of the nose made the further generalization that, "Whether one studies the newborn, the child of eight years or the adult, this part always constitutes 43%." For adult crania of diverse origins, Herzberg and Holic ('43) also found that mean nose height comprised 43.51% of facial height.

Direct measurements of facial segments other than the nose are not available for the present series. However, the fact that the data showed face height and nose height to increase long after completion of the permanent dentition suggested pressing the analysis of the data one step further. Accordingly, proportional relationships were explored in two ways: (1) Calculation of mean nose height as a percentage of mean face height for each year. (2) Analysis of the pattern of increase in the lower portion of the face (subnasale to menton, i.e., mean face height minus mean nose height).

Nose height in percentage of total face height by age is given in table 4. A test for trend shows no significant change in the relative size of the nose during the early adult period ($F = 3.66$, with degrees of freedom 1 and 13; not significant at .05 level).

The fact that, while the face is increasing in size, nose height comprises a constant proportion of face height cannot be taken to mean that the growth rates of the components of the face are the same, or that the rates maintain a constant relationship. Indeed, the opposite is true, for as Gavan ('52,

TABLE 4

Male nose height in percentage of total face height for ages 19 through 33

AGE	NOSE HEIGHT/FACE HEIGHT	AGE	NOSE HEIGHT/FACE HEIGHT
<i>years</i>		<i>years</i>	
19	43.08	27	43.59
20	43.48	28	43.62
21	43.54	29	43.42
22	43.29	30	43.52
23	43.40	31	43.57
24	43.40	32	43.85
25	43.44	33	43.28
26	43.65		

TABLE 5

Values for male subnasale-menton height (mean face height minus mean nose height) (mm) for ages 19 through 33

AGE	SUBNASALE-MENTON HEIGHT	AGE	SUBNASALE-MENTON HEIGHT
<i>years</i>		<i>years</i>	
19	70.30	27	71.52
20	70.35	28	71.57
21	70.55	29	72.06
22	71.06	30	71.99
23	70.74	31	72.05
24	71.43	32	71.75
25	71.55	33	72.36
26	71.25		

p. 133) states in reference to the equation $Y = a + bX$: "... when two measures show a constant relation via a regression equation they will show a changing relation via an index." The difference in rate of growth is further demonstrated by the form of the curve best fitting the data for the segment subnasale to menton. The values for subnasale-menton height, derived from the yearly means, are given in table 5. The best

fitting curve, significant at the .001 level, comprises a diagonal straight line (fig. 3). Therefore, while nose height shows a pattern of slow, decelerating growth, the lower portion of the face undergoes slow, linear increase.

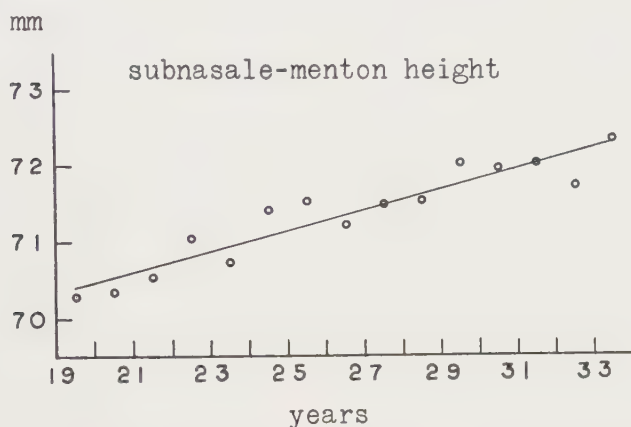


Fig. 3 Age values for subnasale-menton height (mean face height minus mean nose height) of U. S. Army white males from 19 through 33 years, plotted from data listed in table 5. Solid line represents a first-degree curve.

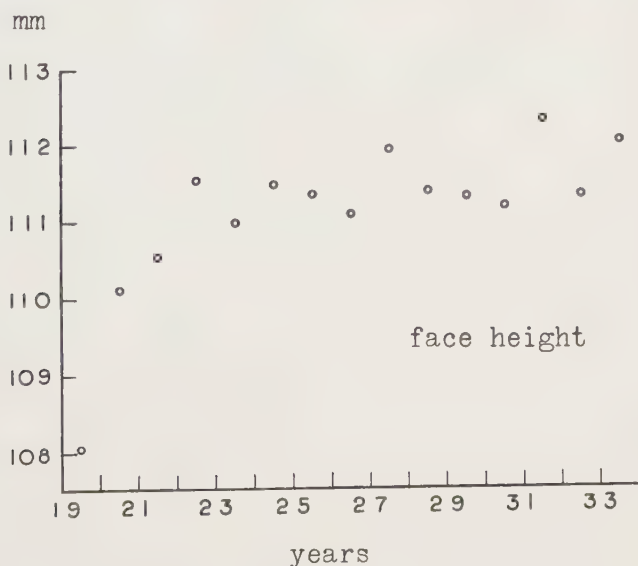


Fig. 4 Mean age values for face height of U. S. Army white females from 19 through 33 years, plotted from data listed in table 1.

Female series

Female face height. The means for female face height from 20 through 33 years are best fitted by a first-degree term, significant at the .01 level (tables 1 and 2). Results of the analysis of variance, however, fail to warrant the conclusion that female face height increases in size appreciably during the early adult period, for the between-group variance is greater than the within-group variance only at the .10 level. However, if a 10% probability of error is accepted, it may be concluded that female face height tends toward a slight linear increase. The means for female face height are shown graphically in figure 4.

The findings for female face height contrast sharply with those obtained for face height in the male. The greater amount and duration of growth of the male face apparently represent a developmental sex difference.

DISCUSSION

The data presented are here discussed (1) in relation to the findings of other anthropometric age change studies reported in the literature, and (2) in terms of some methodological considerations having significance for the interpretation of age change data and the investigation of ontogenetic development.

Size changes in the adult face and head. While supporting the general conclusions of Hellman ('27), Hrdlička ('36), and Lasker ('53) that the human male face continues to increase in size after the adult period has been reached, the data on American military personnel show particular correspondence to the findings of Büchi ('50) on Swiss males and Hooton and Dupertuis ('51) on Irish males. For the age period from 19 through 33 years, the data for total face height are best represented by a decelerating curve approaching a plateau at the later ages. Bizygomatic diameter (face breadth), on the other hand, is characterized by a straight-line curve without suggestion of an approaching plateau. The difference in

the patterns of increase of the two dimensions is reflected in Hooton's and Dupertuis' findings on the Irish series, in which total face height reached maximum size in the 30-34 year age group, while face breadth achieved maximum size in the 60-64 year age group. Correspondingly, Büchi found statistically significant increases in face height through his 38-47 year age group only, although face breadth showed significant increases through the 56-64 year age group. Thus the combined weight of the evidence points to a pattern of size change in which, during the adult period, male face breadth undergoes a slower but more sustained increase than does total face height.

With regard to female face height, however, the present data lend little support to Hrdlička's contention that size increases take place through the fourth decade of life and possibly beyond, for the increase in female face height was found to be significant only at the 10% level. Although Büchi found a statistically significant increase occurring in his 29-38 year female age group, his findings are similar to those of the present study in showing comparatively longer continuance of growth in face height in the male, i.e., through the 38-47 year age group.

The area of greatest difference between the present series and other male series reported in the literature concerns changes in the three head dimensions of length, breadth, and circumference during the adult period. Analysis of these dimensions in the present series showed no significant increase during the third decade of life, while findings for other series range from statistically significant increases through the fifth decade of life to rather indeterminate results suggesting increases in some dimensions but not in others. Thus Büchi's material shows increases in head length and circumference through the 47-56 year age group and increases in head breadth through the 29-38 year age group. Comparably, in their Irish series Hooton and Dupertuis indicate increases in head length and head circumference until at least the 35-39 year age group and attainment of maximum head breadth at 30-34 years. Lasker, on the other hand, concluded that in his

two Mexican series there was little tendency for head length to change with age, although head breadth in the same groups did manifest a tendency to increase with age.

Although Hrdlička subscribed strongly to the position that in general head size increases during adult life, he conceded that his data and the data of others sometimes failed to document increases in individual dimensions. From a descriptive point of view, the variety of findings concerning head size in adulthood lends credence to Hrdlička's conclusion: "The results are not entirely uniform and make it probable that there are some differences in the phenomenon under consideration in contingents of even the same race" ('36, p. 869).

The interpretation of age change data. The investigator reporting anthropometric data showing age changes in adult body dimensions is often hard pressed to demonstrate a specific cause for these changes. Morant ('47), Randall ('49), Hooton and Dupertuis ('51), and Lasker ('53) have discussed the need for recognizing at least three factors, each of which conceivably could be responsible for changing the dimensional age norms of an adult population. These factors are secular change, selective survival, and ontogenetic development. Secular change, it is hypothesized, would result in size differences between two generations of the same population, and possibly even in individuals born a few years apart. Selective survival, it is further hypothesized, would eliminate individuals of less favorable body size or body proportions at correspondingly younger ages, thereby creating size differences within the population when the members are arranged by age. Ontogenetic development is usually regarded as a two-faceted phenomenon in age change studies; that is, such items as gains in fatty tissue with increasing maturity are distinguished from what is considered to be "true growth," actually bony growth.

Earlier in this paper the term "growth" is used to characterize dimensional increases occurring in face height and nose height in a male military population during the third decade of life. Certain questions, therefore, may be legitimately

raised: How does one know that the increase is due to growth? Were secular change and selective survival given due consideration before the dimensional increases were assigned to the growth process? Further, even eliminating secular change and selective survival as causal factors, and granting that the dimensional increases occur as a function of age, is the increased size of the face truly indicative of *bone* growth? What role does soft tissue play in augmenting the size of the face during adulthood?

No additional explanation or defense can be offered here beyond the fact that the data and interpretation advanced in this paper are consistent with the findings of studies of the development of the human head and face during childhood. These studies reveal that the human cranium undergoes an early rapid expansion in conjunction with the growth of the brain, while the face shows sustained growth of longer duration, related to the development of dental occlusion (Krogman, '40). Further, that females achieve their greatest gain in facial growth earlier than males and tend to be about one dental stage in advance of males during the period of mixed dentition (Krogman, '51). The continued growth of the male face into young adulthood, then, represents the terminal phase of the childhood pattern.

Although this conclusion explains the findings in what is believed to be logical fashion, it does not, of course, dispose of the questions put earlier. Nor, in the writer's opinion, can the present cross-sectional anthropometric data provide a definitive answer to these questions. The problem has importance beyond the data here reported, however, and must be explored in terms of the present status of age change studies. The fact that a number of studies describing age changes in body dimensions have been reported and that questions of causality remain unresolved, or at best have been answered only speculatively, would seem to demand an examination of the methods and techniques used in attacking the problem.

With the exception of the remeasurement by Büchi ('50) of the same individuals after a lapse of nine years, the data on

adult age changes reported in the literature represent cross-sectional material. In the field of child development, however, it has long been recognized that the longitudinal method of studying the same individual or group of individuals at successive ages is indispensable if one is to control the variable effects of environment while assessing patterns of development. Individual differences in rate and duration of growth, obscured by the cross-sectional method, are thrown into relief when studied longitudinally. For example, obviously the face does not stop growing at an identical age in all individuals. Again, if certain developmental patterns are found to result in some individuals manifesting greater survival potential than others in the population, this fact, too, is made amenable to analysis by the longitudinal approach.

Although it is true that a longitudinal study of age changes from late adolescence through old age could consume the lifetime of a researcher, or even of several generations of researchers, as Hooton ('51) argued, this fact does not *per se* invalidate the utility or validity of the concept. A modified longitudinal study, utilizing a number of overlapping age classes, is capable of realization within a relatively short time period. But, modified or unmodified, the longitudinal method brings into focus the individual organism, the entity of growth, which merits consideration as the logical unit of study.

The problem of interpretation encountered by Hooton and Dupertuis ('51), resulting from the finding that upper face height in the Irish series increased through 50-54 years, while total face height began to decrease at 35 years, may be cited in this connection. The necessity of invoking both factors of growth and selective survival to account for these findings points to the need for precise determination of changes in the same individuals over an extended period of time.

Turning more specifically to the study of the adult face, the use of roentgenographic techniques will permit a better delimitation of the segments undergoing increase than is pos-

sible with surface measurements. Where are the sites of growth which contribute to further increases in face height after the permanent teeth are fully erupted and in occlusion? Weinmann and Sicher ('47), on the basis of histological data, state that growth continues at the fundus of the tooth and at the free margin of the alveolar process. Studies of the type conducted by Broadbent ('37) and Brodie ('41), if extended to cover the adult period, could test and quantify the leads coming from both anthropometric surveys and comparative histological analyses. For example, the increase reported here as occurring in the anterior height of the adult face (total face height), and reported in the literature for other populations, must involve correlated size changes in other facial segments. It is difficult to conceive of an increase taking place in anterior face height without postulating a parallel increase in the height of the ramus of the mandible; for such a condition would result in a progressively open bite and a changing occlusal relationship. Accurate measurement of the height of the ramus would clarify this problem. Since the measurement of ramal height in the living subject, using conventional anthropometry, presents great difficulties, the application of roentgenography offers a necessary methodological refinement.

However, it is not the purpose of this discussion to engage in a harangue against the conventional anthropometric type of age change study. If it were, the study here reported would not have been undertaken. Nevertheless, it is important to bear in mind the limitations of such a methodology, and in planning future research the need for additional approaches is evident. If it is conceded that some growth processes are operative at wider age spans than previously recognized, the present distinction between childhood and adulthood is clearly arbitrary from a methodological point of view. It must then be concluded that the methods and techniques found effective in child growth studies have equal applicability in the investigation of adult age changes.

SUMMARY

Dimensional changes occurring in the human head and face during the third decade of life are analyzed. The significance of size trends in six dimensions is tested by applying the methods of analysis of variance and curve fitting to cross-sectional anthropometric data, drawn from American military populations of both sexes.

These findings are reported: (1) Male total face height, nose height, and bizygomatic diameter show significant size increases during the third decade of life; during the same period head length, head breadth, and head circumference do not significantly change with age. (2) In the third decade of life female face height does not show a size increase comparable to that occurring in the male. (3) The greater amount and duration of growth in the male face in the third decade apparently represent a developmental sex difference.

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DISTRIBUTION OF ABO GENES IN EASTERN EUROPE

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TWO FIGURES

The publication of the maps showing the world distribution of ABO, MN, and Rh genes by Mourant in his recent book ('54) is an event of considerable importance to geneticists and anthropologists. These maps are based on the analysis of an enormous mass of information, but future research will quite probably amend, to a certain extent, the picture of the distribution of these genes as it emerges from the analysis of data now available. The present paper suggests some adjustments to the map of the distribution of the genes ABO in eastern Europe, the region where the author carried out his own research and with which he is fairly well acquainted. No attempt is made here to analyse critically the distribution of genes ABO in western Europe.

Gene A

1. *Romania*. Investigations by S. Manuila ('24a, '24b), A. Manuila ('43, '45), Popoviciu ('28), Ramneantu and Lustrea ('42), and others, have shown that the frequency of gene A is not higher in the provinces of Banat, south-western Transylvania and Vallachia than in the rest of the country. The provinces of Dobroudja and southern Bessarabia, included by Mourant in the zone 30-35%, a frequency unusually high in eastern Europe, have not yet been investigated. Micu and Micu, and Necrasov ('41a, '41b) have shown that the highest frequency is to be found in the province of Bucovina in the

north of the country as well as in northern Moldavia. High frequencies, as recorded by Mourant, have only been found in a few isolated communities in the mountains and can certainly not be attributed to large regions of Banat, Transylvania, or Wallachia. They raise a complicated anthropological problem, the discussion of which is outside the scope of this paper.

2. *Yugoslavia*. Available data do not seem to support the assumption that the distribution (30–35%) in the north-eastern part of the country is different from that in the south-east. Mourant seems to have taken into account the samples of Kalic and Kostic (77 individuals from Belgrade, 152 from the district of Drinska, 370 from that of Dunavska, and 256 from Moravska) and that of Schmidt ('30) (145 individuals from Sombor and 333 from Sonta). None of these samples, however, is acceptable because the number of individuals examined is too small, because the sample is not sufficiently representative of the population sampled, or because the difference between $p + q + r$ and 1,000 divided by the standard deviation is greater than 2.6, or, finally, because two or even three of these factors together invalidate the results. In my view, none of these samples can be accepted as comparable with the results obtained by Simonovic.

3. *Hungary*. The distribution of the A gene in Hungary raises a difficult problem. A number of workers such as Holló and Lénard ('26), Lenart and Lajta ('36), Somogy and Angyal ('31), and Weitzner ('35), have found in different parts of the country frequencies between 25 and 30%. Mourant, however, included all the south-western part of Hungary in the 30–35% area. It is doubtful that such a zone of high frequency of gene A exists in Hungary. Admittedly, Rosztóczy ('31) found a frequency of 30.5% in 840 individuals from Szegedin; Forró and Gajzágó found 34.0% in 1,000 individuals from Ofenpest (Budapest); Méhely found 37.8% in 473 individuals from Veszprém; and, most recently, Backhausz and Nemeskéri ('55) found 32.0% in 2,615 individuals from Bodrogek, near the Ukrainian frontier. All of these places are outside

the high frequency zone, as defined by Mourant, except Veszprém, which is on its border. Furthermore, the sample from Szegedin showed a frequency of only 0.5 over the 30% higher limit which is found throughout continental Europe. The sample from Ofenpest is doubtful because in the same place several other workers, such as Kiss (4,242 individuals), Lenart and Lajta ('36) (624 individuals), Somogy and Angyal ('31) (1,000 individuals), and Weitzner ('25) (1,000 individuals) have found frequencies below 30%. The sample studied by Méhely showed an extraordinarily high frequency — 37.8% — which strongly suggests that a serological error has invalidated the results. Finally, the population studied recently by Backhausz and Nemeskeri ('55) is located, as already pointed out, near the Ukrainian frontier; and, as the authors themselves remark in their conclusions, it shows evidence of some Ukrainian influences, possibly through mixtures which occur in the region. It seems, in conclusion, that the evidence points rather against the existence of a high frequency gene-A zone in Hungary. This assumption is strengthened by the fact that such a zone does not seem to exist in neighboring Austria or in Yugoslavia.

4. *Austria*. There do not seem to be available any data supporting the assumption that in the northern part of the country the frequency is 25–30% and in the southern, 30–35%.

5. *Albania*. As the relatively recent research by Pannachietti ('42) shows, the frequency of the gene A in Albania is not 25–30%, but rather 20–25%.

6. *Greece*. It is somewhat difficult to understand why Greece has been included in the 20–25% zone when data from Hirszfeld ('19), Diamantopoulos ('28) and Alivizatos ('48) show that this is not the case, since they reveal a frequency of the order of 25–30%. Data obtained by Kumaris ('31) and Hirszfeld ('28) may have been used by Mourant, but the samples which indicate a frequency of the order of 20–25% are all too small to be statistically reliable.

Gene B

1. *Romania*. Northern Bessarabia and Bucovina belong to the 15–20%, not to the 10–15%, zones, as the research of Necrasov ('41a, '41b) and Micu and Micu, the only investigation to be undertaken in these parts of the country, has proved.

2. *Hungary*. An island of higher frequency B seems to exist in central Hungary. Holló and Lénard ('26) and Forró and Gajzágó for example, have found frequencies of 16.6% and 16.8% in Budapest.

3. *Latvia and Estonia*. It seems preferable to incorporate Latvia and Estonia in the 15–20% zone, excepting, perhaps, a narrow littorial stretch. Several statistically significant series support this contention. In Latvia, 1,160 individuals, from all parts of the country, examined by Weidemann ('30) showed a frequency of 18.3%. In Estonia 849 individuals, again from all parts of the country, studied by Raukas, Poska and Reiman, have revealed a frequency of 19.2%. Rooks found in 461 individuals from the north, in 1,844 individuals from the centre, south and south-east, and in 464 individuals from all over the country, proportions of 17.8%, 17.0%, and 17.0%, respectively.

4. *Ukraine*. It is not clear why Mourant included the Ukraine in the 10–15% zone. With the exception of a small island in the region of Kiev, most of the territory seems to belong to the 15–20% zone.

5. *Albania and Greece*. As shown by Pannachietti ('42) in the first country and Hirszfeld ('19), Diamantopoulos ('28) and Alivizatos ('48) in the second, Albania and Greece belong to the 10–15% zone, not to the 5–10% zone. There seem to be no data containing evidence to the contrary.

Gene O

1. *Romania*. Bessarabia, Bucovina, and north-eastern Moldavia do not belong to the frequency zone 60–65%. This has been shown by all investigations (Micu and Micu, Necrasov, '41a, '41b), without exception, undertaken in these provinces.

In the southern part of the country there is a high frequency area which covers most of Vallachia and two districts in southern Transylvania (Sibiu and Fagaras), and one in eastern Oltenia (Ramnicul-Valcea). The existence of this large area where the frequency of gene A is higher than 60% was demonstrated largely through serological investigations, made by the author (Manuila, '43, '45) of 4,695 individuals from nine districts situated in this region.

2. *Ukraine*. There seem to be no data suggesting that the left side of the Dniester to a depth of some hundreds of kilometres belongs also to a 60–65% zone. A few Russian workers have found proportions slightly superior to 60% — for example Folomina found 60.4% in Kiev, and Shirjak found 60.8% in Kherson. As most other findings showed frequencies inferior to 60%, it seems to me unwarranted to make allowance for a 60–65% zone covering a part of the Ukraine and of Romania.

3. *Yugoslavia*. The frequency found in populations in Serbia and Slovenia being in the neighbourhood of 61%, and the number of individuals examined being relatively small, it would appear premature to include on such slender evidence an island with a presumed frequency of 60–65% in the middle of a large area where the frequency is usually under 60%. In any case, it is difficult to see on what basis Mourant assumed that this presumed zone extends from one end to the other of the Adriatic coast. Finally, there seem to be no data indicating the existence in the centre of Yugoslavia of a zone of under-average frequency, 50–55%.

4. *Greece*. It is suggested that most of Greece belongs to the 60–65% zone, as demonstrated by the investigations of Hirszfeld ('19), Diamantopoulos ('28) and Alivizatos ('48) and not to the 65–70% zone (centre and south). The data obtained by certain authors suggesting a possible 65–70% frequency, cannot, in my opinion, be accepted without reservations, since they are open to objection from the methodological and statistical points of view.

TABLE 1

Data supporting suggested adjustments to Mourant's maps of the distribution of ABO genes

POPULATION	AUTHOR	NUMBER TESTED	PHENOTYPES %				GENES %	
			O	A	B	AB	r	p
ROMANIA								
Bucovina	Micu and Micu	4639	24.68	48.50	18.86	7.95	49.7	34.9
Bessarabia (Balti)	Necrasov	860	33.5	39.8	22.14	8.02	57.8	27.4
Bessarabia (Central)	Necrasov	720	33.2	39.4	20.0	7.3	57.6	27.3
Bessarabia (North)	Necrasov	3070	32.8	39.8	20.7	6.6	57.1	26.9
Banat (Caras)	Ramneantu	985	31.8	42.8	15.4	9.9	56.4	30.6
Banat (Severin)	Ramneantu	282	34.4	42.5	17.4	5.7	58.6	28.6
Banat (Timis)	Ramneantu	247	34.8	42.1	17.8	5.3	59.0	28.1
Transylvania (Sibiu)	Ramneantu	1312	37.6	39.5	16.6	6.2	61.4	26.4
Oltenia (R. Valcea)	Ramneantu	275	38.2	40.4	14.5	6.9	61.8	25.4
Vallachia (Muscel)	Manuila	445	41.3	41.6	12.3	4.8	64.3	26.7
Vallachia (Prahova)	Manuila	567	35.3	44.1	15.9	4.8	59.3	29.1
Vallachia (Braila)	Manuila	502	37.1	41.0	17.1	4.7	60.8	26.9
Vallachia (Teleorman)	Manuila	547	37.8	39.3	14.6	8.2	61.5	26.9
Vallachia (Vlasca)	Manuila	525	37.1	40.0	16.2	6.6	61.9	26.9
Vallachia (R. Sarat)	Manuila	500	37.2	40.2	18.0	4.6	61.0	26.3
Vallachia (Buzau)	Manuila	573	39.8	36.7	18.8	4.7	63.1	23.9
Vallachia (Olt)	Manuila	531	36.9	38.4	20.0	4.7	60.7	25.3
Vallachia (Arges)	Manuila	505	41.6	34.5	19.0	4.9	64.5	22.4
YUGOSLAVIA								
Slovenia	Simonovic	616	36.8	42.0	14.9	6.2	60.9	27.9
Croatia	Simonovic	2060	34.1	41.8	16.9	7.3	58.9	28.1
Bosnia	Simonovic	486	33.6	42.8	16.1	7.4	58.0	29.4
Serbia	Simonovic	6863	32.5	41.9	18.2	7.3	57.4	28.8
HUNGARY								
Budapest	Holló and Lénard	400	32.5	40.3	21.7	5.5	57.0	28.3
Budapest	Lenart and Lajta	624	36.1	41.8	15.9	6.2	60.1	28.2
Budapest	Somogy and Angyal	1000	33.1	42.6	18.0	6.3	57.6	29.4
Budapest	Weitzner	1000	35.7	43.3	15.7	5.3	59.8	29.2
Bodrogköz	Backhausz and Nemeskéri	2615	27.9	45.6	18.3	8.1	52.8	32.0
BULGARIA								
Sofia	Seisov	500	31.4	43.8	17.6	7.2	56.0	30.7
Sofia	Ganev	6060	32.1	44.4	15.4	8.1	56.7	30.8
Sofia (?)	Zontchev	500	29.8	45.8	15.4	9.0	54.6	32.4
Unspecified	Gaserova	767	32.3	43.4	16.5	7.8	56.8	30.2
GREECE								
Athens	Diamantopoulos	1200	42.0	39.6	14.2	3.7	64.8	25.4
Whole country	Alivizatos	18325	40.7	39.3	17.8	5.2	63.0	25.5
Unspecified	Hirszfeld and Hirszfeld	500	38.2	41.6	16.2	4.0	61.8	26.2
ALBANIA								
Whole country	Pannachietti	1023	35.2	41.4	17.4	5.9	64.4	23.3

DISCUSSION

Evidence supporting the suggested adjustments to Mourant's map is given in table 1. Some of the data are not included in the tables and bibliographies of Steffan ('32), Boyd ('39), Mourant ('54), or Wiener ('48), and have apparently never been referred to in the literature. Publication in journals not readily accessible, or in languages known to few workers in the field, may explain to some extent why these important data have been overlooked.

The relevant areas of Mourant's original maps are reproduced (fig. 1) with the permission both of the author and of the publisher. Figure 2 shows the distribution of genes ABO as they appear when my suggested amendments are made.

It will be seen that the most important change in the map showing the distribution of the gene A is the reduction of the large 30-35% area which covers parts of Romania, Hungary, Austria, Yugoslavia, and Bulgaria to a much more limited area covering only Bulgaria and small regions in Romania. Even the zone covering Bulgaria is somewhat doubtful since the investigations of Ganev, Seisov, Gaserovala and Zontchev have revealed a frequency only slightly superior to 30% (mostly around 30% with a maximum of 32.4%). Whether such a small difference warrants the inclusion of an island in a very large area covering practically the whole of Europe west of a line linking the White and Caspian Seas is a matter of speculation, the more so that A-gene frequencies inferior to 30% have been found in Bulgaria. Another change would be the transfer of Greece from the 20-25% zone to the 25-30% zone.

The map of the distribution of gene B should preferably be re-shaped so that the 15-20% zone is extended to include the Baltic countries, with the exception of a narrow littoral zone and of Lithuania; the whole of the Ukraine, with the exception of a possible very small area in the region of Kiev; Bessarabia; and Bucovina. Three very small zones of relatively high gene-B frequency (15-20%) appear to exist in the centre of Hungary and in central and southern Romania. Finally, Greece

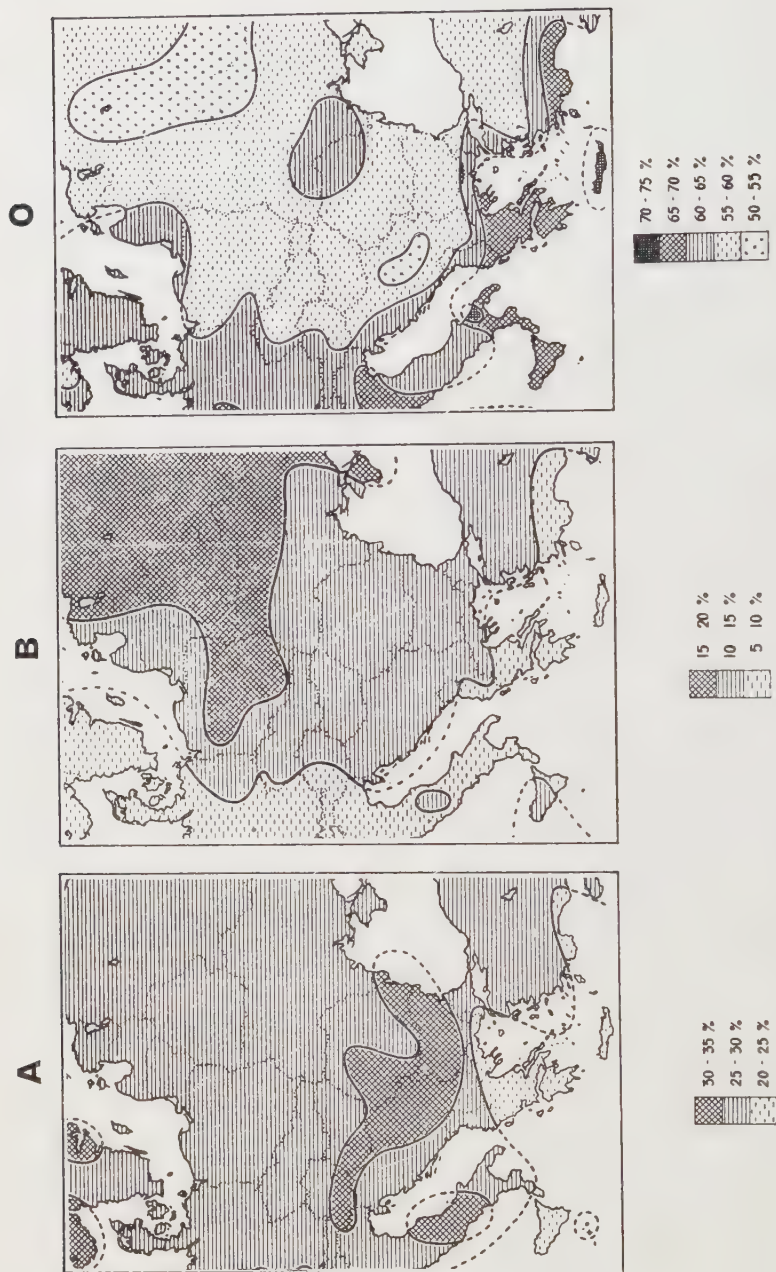


Fig. 1 Mourant's original map of the distribution of genes ABO in central and eastern Europe.

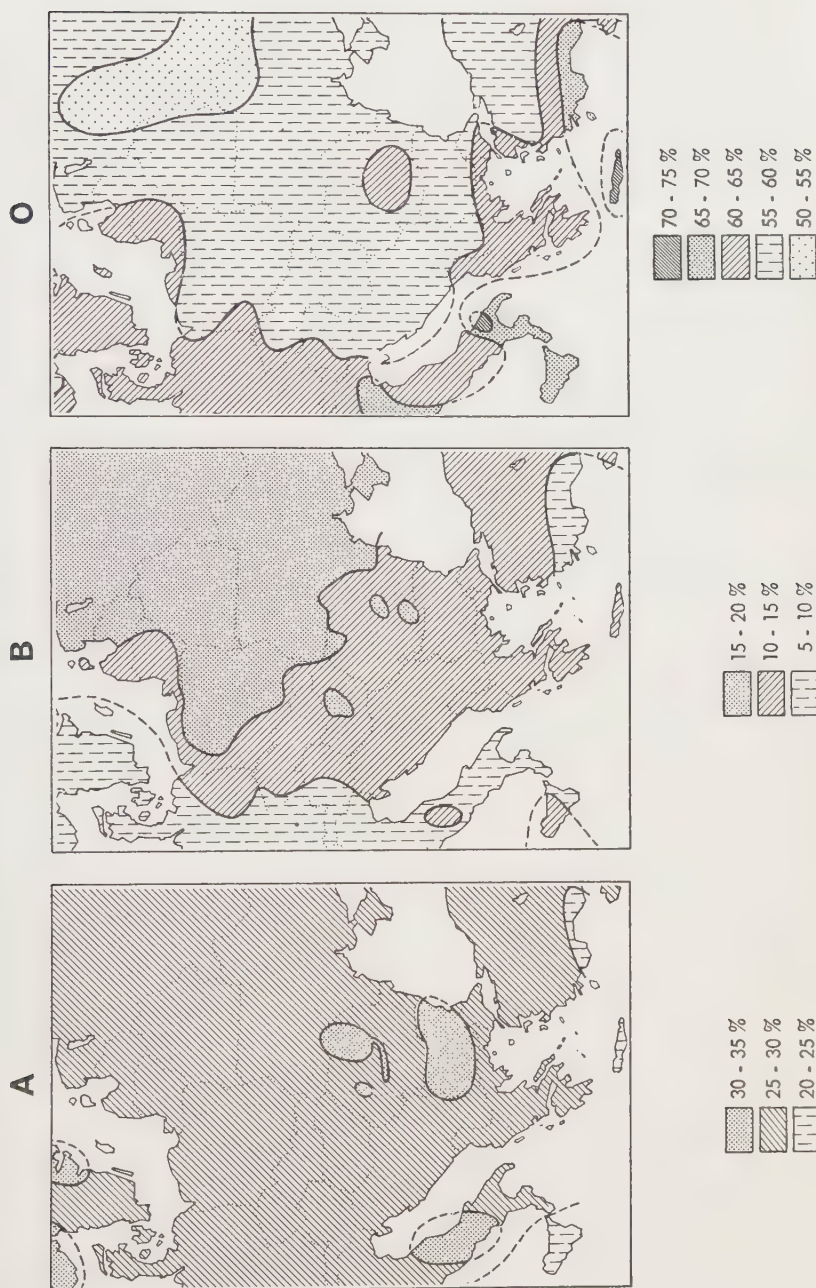


Fig. 2 Adjusted map of the distribution of genes ABO in central and eastern Europe.

seems to belong to the 10-15% zone rather than the 5-10% one.

On the map showing the distribution of gene O, the changes are the deletion of the 60-65% zone covering part of the Ukraine and of Romania and of another small area of the 50-55% zone in central Yugoslavia; the inclusion of the whole of Albany and Greece in the 60-65% zone rather than the 65-70% zone; and the recognition of a 60-65% zone covering Vallachia and small parts of Transylvania and Oltenia, in Romania.

Dr. Mourant, who has examined a copy of this paper before publication, has commented on it as follows: "In many, perhaps most, cases, your alterations make the map more correct and complete, but in some cases I think that the data given by Boyd might improve even your map." In fact no data from Boyd's monograph ('39) have been overlooked here; but I have discarded some series taken into consideration by Mourant which in my opinion are too small, or which suffer from other imperfections, such as too great a heterogeneity or the fact that the difference between $p + q + r$ and 1,000 divided by the standard deviation is greater than 2.6. The most important adjustments to Mourant's map result, however, not from these differences in our use of the material, but from the fact that various data were not available to Mourant at the time he completed his maps. In particular, Mourant was unable to use the fundamental data regarding Yugoslavia provided by Simonovic in his maps, although he managed to include these data in his tables, and did not have access to other equally significant data made available by Alivizatos ('48) for Greece; Manuila ('45), Necrasov ('41a, '41b), and Ramneantu and Lustrea ('42), for Romania; Pannachietti ('42), for Albania; and Backhausz and Nemeskéri ('55) for Hungary.

It may be of interest to anthropologists to know that Dr. Ada Kopec, of the Nuffield Blood Group Centre, England, is currently compiling all published data on ABO frequencies for the whole world, and that Dr. Mourant is planning to revise his maps when this work is completed. It is to be hoped

that anthropologists and serologists who publish data in journals which are not easily accessible will keep Dr. Mourant informed of their findings and make suggestions for the completion of his maps.

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¹ Data for which no references are given in this list have been taken either from Boyd ('39) or from Steffan ('32).

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ESTIMATION OF SKELETON WEIGHT IN THE LIVING¹

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The weight of the skeleton is due, only in part, to the size or the volume enclosed by the surface of its individual bones. The size of the bones is determined by the many factors included in both heredity and environment. It is generally believed that after growth is completed there is no significant change in the size of the normal skeleton, or of any bone comprising it, throughout the life span. However, bones are living organs and their maintenance is dependent on metabolic processes which may be affected by many factors, including stress, activity, growth and aging. Evidence of these effects is apparent in the internal structure of a bone through alteration in the amount and density of its deep, spongy substance (*substantia spongiosa*) and its superficial, compact substance (*substantia compacta*).

Koch ('17) considered the conformation of the intrinsic structures of the femur to be the result of adaptation to stress of pressure and function. A more realistic view has been presented by Murray ('36) who recognized that the primary patterns of the skeleton are well defined early in life and that environmental conditions act as modifiers of the hereditary intrinsic patterns. The importance of functional stresses in maintaining the characteristic structures of bones is indicated by the work of Amprino ('38) who showed that, when normal movement of the limbs is inhibited, degenerative processes akin to osteoporosis set in. Sperling et al. ('55) studied

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the effects of different diets on long bones of rats. Rats fed on a milk diet throughout their life span had denser bones in old age than those fed on standard diets. When the diet is deficient in calcium, the level of calcium in the blood is held constant through release of reserve calcium which had been stored in the bone trabeculae at a time when the dietary intake exceeded the amount necessary for maintenance and growth (Sherman, '52). It was pointed out by Amprino ('43) that the rate of bone growth is a determining factor in the "quality" of the bone formed. In the bones of an acromegalic giant he found that the haversian systems or osteones were larger and more numerous as were, also, the erosion cavities. On the other hand, a proportionate dwarf of approximately the same age had smaller and fewer osteones and erosion cavities and the fundamental lamellar systems were abundant.

Less is known about the influence of race and sex on the finer structures than on the gross morphology of bone. It is well known that the long limb bones of Negroes are longer relative to their stature than of Whites, and that their forearms and legs are longer in proportion to their arms and thighs, respectively, than in Whites (Trotter and Gleser, '52). They have shown also a definite increase in mean stature and femur length of adult American Whites and Negroes born during the first quarter of this century ('51). These increases may be attributed to shifting of environmental and, perhaps, hereditary factors, however subtle and difficult these may be to analyze.

It can be seen in sections and radiographs that the long limb bones of man have large amounts of compact bone which, accordingly, must contribute a significant portion of their weight. This is particularly true of the femur, the largest and heaviest single bone in the skeleton. Characteristically, the femur has a long cylindrical shaft of which the superficial compact portion is relatively thick and reliably measurable.

A preliminary study of estimation of weight of the dry, fat-free skeleton was based on 24 White male skeletons in the Terry Collection (Trotter, '54). Various measurements

which may be taken on the living subject were tested for correlation with weight of the total skeleton. The results were sufficiently promising to warrant further investigation.

The purpose of the present study is to increase the series of White male skeletons in order to evaluate the earlier results; to extend the study to White females and to Negroes of both sexes; and, to derive formulae which will provide a reliable estimate of weight of the dry, fat-free skeleton in living American Whites and Negroes.

MATERIAL

The skeletons used in this study were selected from the Terry Collection which has been derived from cadavers assigned to the Department of Anatomy by the Missouri Anatomical Board. All skeletons have been subjected to the same process of maceration and preparation. A complete description of these methods of preparation has been recorded elsewhere (Trotter, '54). Age, sex, race and fragmentary data on cause of death are known for all skeletons. In all but four, measurements of stature of the cadaver when received had been recorded.

Selection of the skeletons was made for relatively equal distribution in each decade after adult age. Skeletons with obvious pathological conditions, or with any but minor parts missing or broken, were not included. The relatively small number of White female skeletons in the Collection made it necessary to include in this group four skeletons from cadavers on which stature had not been measured. For these, cadaver stature was estimated from the average maximum length of tibiae and femora according to formula (7)² as reported by Trotter and Gleser ('52). These estimates are included with other stature measurements of White females and treated in the same way in all statistical analyses involving data on stature.

² Formula (7): $1.39 (\text{Fem}_m + \text{Tib}_m) + 55.70 = \text{Cadaver Stature (cm)} \pm 3.55 \text{ cm.}$

The distribution of the sample according to race, sex and age is given in table 1.

TABLE 1

Distribution of skeletons according to race, sex and age

RACE	SEX	AGE INTERVAL (YEARS)							TOTAL
		16-29 ¹	30-39	40-49	50-59	60-69	70-79	80-91 ²	
White	Male	4	8	9	9	9	8	8	55 ³
Negro	Male	8	8	9	8	8	8	5	54
White	Female	1	6	4	7	8	8	5	39
Negro	Female	12	7	8	8	6	9	5	55
Total		25	29	30	32	31	33	23	203

¹ All skeletons in this column are included in a 20-29 year span with the following exceptions: 1 White male, 18 years; 2 Negro males, 18 and 19 years; 1 White female, 17 years; and 4 Negro females, 16 years, 17 years and two 19 years.

² All skeletons in this column are included in an 80-89 year span with the following exceptions: 1 Negro male, 91 years; 1 White female, 90 years; and 1 Negro female, 91 years.

³ Among this group of skeletons are included the 24 which served as material for the preliminary study (Trotter, '54).

METHOD

Weights of the skeleton were determined on a Toledo beam balance. This instrument is fitted with two weighing pans, one of which is used for weights up to 302 gm with an accuracy of 0.1 to 0.2 gm, while the other is used for weights from 302 to 3024 gm (capacity) with an accuracy of 1 to 2 gm. Each bone was weighed separately except for hand bones, foot bones and the ribs which were grouped according to side and weighed; the movable vertebrae were separated into cervical, thoracic and lumbar segments and weighed as groups; and, the coccyx, or any part of it, was weighed only when fused to the sacrum. The hyoid bone and auditory ossicles were not included. The skeleton as a whole was then weighed, usually in two parts. The sum of the weights of the individual bones was checked against that of the total skeleton. When the two values fell within a range of 8 gm they were considered to be in agreement. When there was a larger dis-

crepancy between the two, the source of the difference was sought and the error corrected.

The femurs were radiographed at 30 milliamperes and 60 kilovolts with $\frac{1}{4}$ second exposure. They were arranged, two pairs at a time, on a cassette (14×36 inches) for a posterior-anterior view and the tube was placed at a distance of 72 inches from the center of the cassette. The films were developed in the Mallinckrodt Institute of Radiology through courtesy of Professor Hugh Wilson.

The maximum length of the image of each femur on the film was measured with a metal rule. The middle half of the length of the image was then determined and marked off on the film. Two planimeter readings were made: one, of the area enclosed within the outer boundary of the middle half of the femur (hereafter referred to as the area of the shaft); the second, of the area enclosed within the inner boundary of the compact bone in the middle half of the femur. The difference between these two measurements is considered to be the area of the compact bone in the middle half of the femur. The planimeter was set so that the readings could be read directly in square centimeters with an accuracy of 0.1 cm^2 . Repeated trials have shown that three consecutive readings of the same area that give values within a range of 0.5 cm^2 are of sufficient accuracy for the purpose. The percent of compact bone in the middle half of the femur was derived by dividing the area of compact bone by the area of the shaft. For each skeleton the above determinations were obtained separately for right and left bones; the two figures were then averaged.

Statistical analyses of the data include correlation coefficients, multiple correlation coefficients and regression equations derived from them with tests of significance for the standard partial regression coefficients (Snedecor, '46; Johnson, '49). The measure of variability is the standard deviation; and, the standard error of estimate is the means for characterizing the precision of the estimation equations. The methods of statistical analyses were selected by Barbara

Bartels Hixon. Her interest and cooperation throughout this and the preliminary study are gratefully acknowledged.

RESULTS

The data comprise 7 independent variables denoted by X_1 , each with its appropriate subscript and the dependent variable, Y , the weight of the skeleton. The independent variables for each skeleton are:

- X_1 Age (years).
- X_2 Cadaver stature (cm).
- X_3 Average maximum length of femurs (cm).
- X_4 Average area of middle half of femurs determined from radiographs, posterior-anterior view (cm^2).
- X_5 Average area of compact bone in middle half of femurs determined from radiographs, posterior-anterior view (cm^2).
- X_6 Average area of compact bone in percent of average area of middle half of femurs ($100X_5/X_4$).
- X_7 Average weight of femurs (gm).

The skeletons were selected in order to make each of the four groups as representative and comparable for age range as the Terry Collection permits. Nevertheless, the mean age of the Negro groups is younger than of the White groups. For all four groups, however, the means lie within the sixth decade (table 2).

It may be seen in each group that the mean stature shows minor variations from decade to decade with smaller means in the older age periods, and that the mean femur length is relatively constant throughout the age range. This discrepancy may be attributed to the fact that in adults stature shows a decrease with increase in age, and that femur length is unaffected by aging (Trotter and Gleser, '51a). The mean area of the shaft is smaller in the younger age groups than in the succeeding ones of all four divisions, and, whereas the variations between the decades are more marked than in stature, there is no suggestion of a trend after growth is completed.

CASES	INTERVAL	X ₁ AGE		X ₂ STATURE		X ₃ FEMUR LENGTH		X ₄ AREA SHAFT		X ₅ AREA COMPACT		X ₆ % COMPACT		X ₇ FEMUR WEIGHT		Y SKELETON WEIGHT	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
no.		years		cm		cm		cm ²		cm ²		X ₅ /X ₄		gm		gm	
White male																	
4	18-29	21.5	4.4	172.0	12.3	46.2	3.1	60.4	12.4	26.8	7.1	44.2	6.3	364	100	4445	999
8	30-39	35.1	3.4	173.1	10.5	46.2	4.4	68.0	9.1	29.2	2.9	43.5	6.4	388	68	4245	624
9	40-49	44.9	3.0	173.0	7.0	46.2	2.0	70.9	5.6	32.1	4.5	45.6	8.1	435	70	4860	710
9	50-59	55.8	4.0	171.7	4.7	46.1	2.6	68.9	5.5	30.1	3.9	43.6	2.7	395	51	4369	569
9	60-69	66.2	2.3	172.1	4.9	46.3	1.7	71.0	5.1	31.3	4.1	44.0	3.8	415	70	4432	701
8	70-79	73.6	3.3	168.1	2.8	46.3	1.5	69.8	3.1	30.2	3.5	43.3	4.7	410	34	4575	349
8	80-87	82.9	2.5	168.9	7.5	46.0	2.4	69.3	7.5	27.0	3.0	39.1	3.9	358	46	3955	457
55	18-87	56.7	18.8	171.3	7.0	46.2	2.5	69.0	6.9	29.8	4.2	43.3	5.4	398	64	4417	646
Negro male																	
8	18-29	24.1	4.3	174.9	7.0	48.6	3.2	70.2	9.4	29.7	3.3	42.5	2.6	448	71	4915	715
8	30-39	34.2	2.9	178.5	4.4	49.9	2.0	76.2	4.9	33.8	4.7	44.3	4.2	512	65	5621	675
9	40-49	45.7	2.8	170.6	8.4	47.6	4.0	70.2	10.8	31.3	3.6	44.9	3.6	439	94	4882	1009
8	50-59	56.2	2.3	171.4	5.7	48.0	2.1	73.1	7.3	34.2	5.1	46.7	4.1	451	81	4976	890
8	60-69	62.8	3.5	167.9	10.2	48.7	2.1	74.6	8.8	35.8	4.2	47.7	5.5	477	76	4988	480
8	70-79	73.6	3.5	172.8	10.4	48.7	3.5	76.0	11.5	31.5	3.0	42.3	7.4	477	126	5340	946
5	80-91	86.4	4.2	167.8	6.4	46.8	1.8	72.3	4.2	31.0	3.1	43.0	4.0	390	50	4611	832
54	18-91	52.8	19.6	172.2	8.2	48.4	2.8	73.2	8.6	32.5	4.2	44.6	4.9	460	86	5069	822
White female																	
7	17-39	30.0	6.2	163.3	5.0	42.9	2.8	54.5	4.2	22.0	3.0	40.5	5.6	265	38	3197	543
4	40-49	46.5	1.7	161.2	7.8	42.8	2.8	58.9	10.3	20.8	7.1	34.7	6.6	264	105	3002	844
7	50-59	55.0	2.1	164.6	5.8	44.4	1.0	61.5	5.4	24.4	3.8	39.9	5.9	290	58	3320	507
8	60-69	65.0	2.9	158.1	7.4	42.2	2.4	56.4	3.0	18.7	4.0	33.2	7.5	231	31	2984	400
8	70-79	73.0	2.7	161.4	7.8	43.6	2.3	61.3	6.9	17.3	7.0	28.0	11.0	255	67	3022	709
5	80-89	86.4	3.4	153.6	8.3	42.5	2.2	61.9	6.0	11.2	3.7	18.0	4.9	192	51	2182	400
39	17-89	59.4	18.3	160.6	7.4	43.1	2.3	58.9	6.3	19.3	6.1	32.8	10.2	251	62	2989	630
Negro female																	
12	16-29	22.2	3.9	161.6	8.4	43.5	1.9	55.2	5.0	22.8	2.5	41.4	4.8	316	46	3736	487
7	30-39	35.7	3.5	162.1	8.1	44.8	2.9	59.9	6.8	24.8	3.9	41.3	3.0	333	83	4030	790
8	40-49	44.5	2.6	164.4	6.9	46.0	2.3	62.9	6.0	26.4	5.4	42.0	7.8	346	61	3920	646
8	50-59	54.8	3.3	160.0	3.5	43.6	1.4	58.4	3.4	25.6	4.7	43.6	5.9	291	50	3388	443
6	60-69	63.8	2.2	158.8	3.5	43.1	1.5	60.9	5.5	23.4	3.4	38.5	5.3	325	74	3827	656
9	70-79	73.0	3.1	160.0	5.6	44.7	1.9	60.9	3.8	20.8	6.0	33.9	9.1	297	68	3373	634
5	80-91	83.8	4.5	158.4	7.5	44.9	3.2	63.7	6.7	22.8	1.7	36.1	4.4	289	51	3286	612
55	16-91	50.2	20.7	161.0	6.5	44.3	2.2	59.7	5.7	23.7	4.4	39.8	6.7	314	61	3659	628

The mean area of compact bone is smaller, also, in the youngest age groups than in middle decades but, unlike the area of the shaft, this variable shows a tendency to decrease in the later age periods. This tendency is especially pronounced in the White females where the mean area of compact bone decreases from 24.4 cm² in the sixth decade to 11.2 cm² in the ninth decade.

TABLE 3

Means, standard deviations (S.D.) and coefficients of variation (C.) of the variables according to race and sex

	X ₁ AGE	X ₂ STATURE	X ₃ FEMUR LENGTH	X ₄ AREA SHAFT	X ₅ AREA COMPACT	X ₆ % COMPACT	X ₇ FEMUR WEIGHT	Y SKELETON WEIGHT
	years	cm	cm	cm ²	cm ²	X ₆ /X ₄	gm	gm
<i>White male (55)</i>								
Mean	56.7	171.3	46.2	69.0	29.8	43.3	398.3	4417.0
S.D.	18.8	7.0	2.5	6.9	4.2	5.4	63.8	645.8
C. (%)	33.2	4.1	5.4	10.0	14.1	12.5	16.0	14.6
<i>Negro male (54)</i>								
Mean	52.8	172.2	48.4	73.2	32.5	44.6	459.6	5068.9
S.D.	19.6	8.2	2.8	8.6	4.2	4.9	86.1	821.9
C. (%)	37.1	4.8	5.8	11.7	12.9	11.0	18.7	16.2
<i>White female (39)</i>								
Mean	59.4	160.6	43.1	58.9	19.3	32.8	251.0	2989.3
S.D.	18.3	7.4	2.3	6.3	6.1	10.2	61.6	629.6
C. (%)	30.8	4.6	5.3	10.7	31.6	31.1	24.5	21.1
<i>Negro female (55)</i>								
Mean	50.2	161.0	44.3	59.7	23.7	39.8	314.2	3659.2
S.D.	20.7	6.5	2.2	5.7	4.4	6.7	61.5	627.6
C. (%)	41.2	4.0	5.0	9.5	18.6	16.8	19.6	17.2

The per cent of compact bone represents the amount of compact bone relative to the size of the shaft that contains it. It is interesting to note that this relationship is less constant among females of both races than among males. In both female groups there is a decrease in the percentage of compact bone after 60 years of age. Although the size of the femur, expressed in length and area of shaft, is not altered after growth is completed, area of compact bone shows a

reduction in the later decades of life. This reduction is greatest in the White females where the amount of compact bone is decreased from 39.9% in the 50-59 year decade to 18.0% in the 80-89 year decade.

Femur weight shows variations from decade to decade with a tendency to be lighter in the younger age groups. In the oldest age groups there is a reduction which is more pronounced in females of both races than in males. The mean skeleton weight in each group shows variations with age which are similar to those shown by femur weight.

The means, standard deviations and coefficients of variation of each variable are presented according to race and sex in table 3. Stature and femur length exhibit only small and relatively uniform coefficients of variation in each of the four groups (stature from 4.0% to 4.8% and femur length from 5.0% to 5.8%), whereas area of shaft shows somewhat greater tendency to deviate from the group means (9.5% to 11.7%). It has already been suggested (see table 2) that these three variables change little, if at all, with age, and the variations may be assumed to reflect individual hereditary differences rather than effects of external factors during life.

The coefficients of variation of area of compact bone are greater in females of both races (31.6% and 18.6% than in males (14.1% and 12.9%); and, the coefficient is greater in the White female group than in the Negro female group. The coefficients of variation of per cent of compact bone are essentially the same in White and Negro males, 12.5% and 11.0%, respectively, but are increased to 16.8% in Negro females and to 31.1% in White females. Femur weight and skeleton weight both show smaller coefficients of variation in males than in females. In males, comparison of the coefficients of variation shows that Negroes exceed Whites in femur weight (18.7% and 16.0%) and in skeleton weight (16.2% and 14.6%). On the other hand, in females the Whites exceed the Negroes in the coefficient of variation of femur weight (24.5% and 19.6%) and of skeleton weight (21.1% and 17.2%).

Thus, it is evident that in the variables, area of compact bone, per cent of compact bone, femur weight and skeleton weight, the standard deviations and the means are not as uniformly related in all four divisions of the sample as in the variables, stature, femur length and area of shaft. The latter three variables are all expressions of the size of the skeleton and normally undergo little, if any, change during the span of adult life. On the other hand, the amount of compact bone and the weight of the skeleton, or any of its individual parts, are expressions of the size, to be sure, but also of the internal structure of the skeleton which may be altered by changing environment during the life span.

Single correlations. The correlation coefficients, r , of each independent variable, X_i , with skeleton weight, Y (the dependent variable), and the associated probability, P , where significant, are presented in table 4 for each group. In addition, the correlation coefficients of certain independent variables with each other are given.

The variable, age, was tested for correlation with each of the other variables; the coefficient was found to be negative in most instances and significant in only a few. The correlation coefficients of age with stature are all negative and significant only in the Negro male and White female groups ($P < .05$). Age of femur length are not significantly correlated in any group. Age and area of shaft are significantly correlated only in the Negro female group ($P < .01$). The coefficients of correlation between age and area of compact bone are very low for all groups except the White female for which it is $-.5306$ with $P < .001$. Similarly, the correlation coefficients of age with per cent of compact bone are not significant in either male group, but are significant at the .02 level in Negro females and at the .001 level in White females. The correlation of age with skeleton weight is negative in each group and the coefficient is significant only in the White female group at the .05 level.

The correlation coefficients between stature and femur length are highly significant in all four groups. These coeffi-

Correlation coefficients (r) of each independent variable with skeleton weight and of certain independent variables with each other, and probability (P) of each where significant, according to race and sex. The order of White male, Negro male, White female and Negro female is followed in each series

	X_1 AGE		X_2 STATURE		X_3 FEMUR LENGTH		X_4 AREA SHAFT		X_5 AREA COMPACT		X_6 % COMPACT		X_7 FEMUR WEIGHT	
	r	P	r	P	r	P	r	P	r	P	r	P	r	P
X_2 Stature	-.2036													
	-.3108	<.05												
	-.3615	<.05												
	-.1717													
X_3 Femur length	-.0073		.8473	<.001										
	-.1649		.6709	<.001										
	-.0788		.8064	<.001										
	.1001		.5527	<.001										
X_4 Area shaft	.2166		.6656	<.001	.7261	<.001								
	.0902		.4475	<.001	.8101	<.001								
	.2973		.5547	<.001	.7410	<.001								
	.3807	<.01	.3569	<.01	.6686	<.001								
X_5 Area compact	-.0158		.4238	<.01	.3382	<.02	.5569	<.001						
	.0786		.1423		.3938	<.01	.5539	<.001						
	-.5306	<.001	.5728	<.001	.4246	<.01	.2278							
	-.1205		.2714	<.05	.4332	<.001	.3725	<.01						
X_6 % compact	-.2011													
	.0260													
	-.6480	<.001												
	-.3448	<.02												
Y Skeleton weight	.1359		.5126	<.001	.4203	<.01	.5002	<.001	.6091	<.001	.2656	=.05	.9030	<.001
	.1141		.4804	<.001	.4880	<.001	.5720	<.001	.4327	<.01	.0842		.9079	<.001
	.3431	<.05	.5144	<.001	.3289	<.05	.2186		.7078	<.001	.6554	<.001	.8844	<.001
	.2633		.2631		.3143	<.05	.4607	<.001	.4686	<.001	.2536		.9219	<.001

cients are, however, as in the correlations between stature and area of shaft, higher for Whites of both sexes than for the corresponding Negro groups. Femur length is highly correlated with area of shaft. In these three series of correlations the coefficients are all significant at the .001 level of probability except in the Negro female group where stature tested with area of shaft gives a correlation coefficient of .3569 with a probability of $< .01$. Thus, it may be said that these three variables are all closely related and that, in general, this relationship is higher in Whites than in Negroes. Stature shows a highly significant relationship with area of compact bone for both White groups but the relationship is not significant in the Negro male group and significant only at the .05 level in the Negro female group. The correlation coefficient of stature with skeleton weight is highly significant except in the Negro female group.

In the correlations of femur length with area of compact bone the coefficients are significant for White males at the .02 level, for Negro males of the .01 level and, for White females at the .01 level and for Negro females at the .001 level. Femur length is more highly correlated with skeleton weight in both male groups than in the female groups, but only in the Negro male group is the coefficient significant at the .001 level.

The correlation coefficients between area of shaft and area of compact bone are highly significant for White and Negro males; the Negro females have a lower correlation coefficient between these variables than have the males and in the White female group the coefficient is not significant. These differences suggest that area of compact bone varies more independently of area of shaft in females than in males and more so in White females than in Negro females. The correlation coefficients between area of shaft and skeleton weight are significant at the .001 level, except for the White female group for which the coefficient is not significant. Thus, area of shaft is correlated significantly with area of compact bone and with skeleton weight in all groups except the White female group.

The variables, area of compact bone and skeleton weight, are correlated at the .001 level for all groups except the Negro male where the level of significance is at the .01 level.

The per cent of compact bone is highly correlated with skeleton weight only in the White female group; the relationship is significant at the .05 level for White males and is not significant in either Negro group.

Femur weight and skeleton weight have high correlation coefficients in all four groups indicating that the factors which affect the weight of the femur affect the weight of the other bones comprising the skeleton as well.

Thus, the White female is shown to differ from the other groups, by lack of a significant correlation between area of shaft and area of compact bone and between area of shaft and skeleton weight. Further, it is the White female group only in which there is a highly significant correlation coefficient between age and area of compact bone and between age and per cent of compact bone; and, the only group in which there is a significant correlation between age and skeleton weight; in each of these three correlations the coefficient is negative. These differences of the White female from the other groups indicate that reduction in both amount and per cent of compact bone of the femur (and of the skeleton?) occurs during aging of White females.

Multiple correlations. Although the correlation coefficients (r) between skeleton weight and several of the independent variables are highly significant and would lead to good estimates of skeleton weight, certain combinations of these independent variables yield multiple correlation coefficients (R) which would provide even better estimates of skeleton weight. These statistics and the corresponding standard errors of estimate are summarized in table 5. In order to determine which of the independent variables, age, stature, femur length, area of shaft and area of compact bone, in combination, contribute significant information to estimates of skeleton weight, multiple regression studies were made using these five independent variables.

TABLE 5

Correlation coefficients (r) of certain independent variables with skeleton weight; multiple correlation coefficients (R) of X_1, X_2, X_3, X_4 and X_5 and of the most efficient combinations of these variables with skeleton weight; and the standard errors of estimate (grams)

INDEPENDENT VARIABLES	WHITE MALE			NEGRO MALE			WHITE FEMALE			NEGRO FEMALE		
	r_{X_1Y}	R	S.E.Est.	r_{X_1Y}	R	S.E.Est.	r_{X_1Y}	R	S.E.Est.	r_{X_1Y}	R	S.E.Est.
X_2 , Stature	.5126		559.8	.4804		727.7	.5144		547.1	.2631		611.2
X_3 , Femur length	.4203		591.6	.4880		724.2	.3289		602.6	.3143		601.4
X_4 , Area of shaft	.5002		564.5	.5720		680.6	.2186		622.6	.4607		562.3
X_5 , Area of compact bone	.6091		517.1*	.4327		748.0	.7078		450.7*	.4686		559.6
X_1 (age), X_2, X_3, X_4, X_5		.6796	497.4		.6687	642.1		.7348	458.3		.7015	469.5
X_2, X_4					.6247	654.3*					.6864	469.7*
X_3, X_4, X_5												

* Variable or variables contributing significantly to information when standard partial regression coefficients in multiple regression equations involving variables X_1, X_2, X_3, X_4, X_5 are analyzed by t test.

TABLE 6

Tests of significance ($t = \frac{b'}{s_{b'}}$) of standard partial regression coefficients (b')* and probability (P) of each where significant, according to race and sex

INDEPENDENT VARIABLE	WHITE MALE			NEGRO MALE			WHITE FEMALE			NEGRO FEMALE		
	$\frac{b'}{s_{b'}}$	t	P	$\frac{b'}{s_{b'}}$	t	P	$\frac{b'}{s_{b'}}$	t	P	$\frac{b'}{s_{b'}}$	t	P
X_1	-.1151 .1244	= -.93		-.1145 .1207	= -.95		.1218 .1844	= .66		-.4827 .1224	= -.3.94 < .001	
X_2	.2350 .2256 = 1.04			.3787 .1525 = 2.48 < .02			.3824 .2408 = 1.59			-.0278 .1279 = -.022		
X_3	-.0394 .2250 = -.17			-.3149 .2332 = -1.35			-.2592 .2489 = -1.04			-.1886 .1574 = -1.20		
X_4	.1553 .1906 = .81			.5546 .2185 = 2.54 < .02			.0118 .2160 = .05			.6901 .1562 = 4.42 < .001		
X_5	.4345 .1317 = 3.30 < .01			.2046 .1304 = 1.57			.6608 .1623 = 4.07 < .001			.2426 .1180 = 2.06 < .05		

A set of five normal equations for each group was determined from the intercorrelation coefficients (see table 4) of the variables (X_1 through X_5 and Y). Each set was modified to form five systems of simultaneous equations which were solved for Fisher's auxiliary statistics (g_{ij}) as in Johnson ('49). From these auxiliary statistics the standard partial regression coefficients and their standard errors were calculated. The standard partial regression coefficients were tested for significance by the t test (table 6). It is seen that according to the group under consideration significant information can be obtained from one, two or three of the variables.

In the White male group the t test, when applied to the standard partial regression coefficients, indicates that the independent variable, area of compact bone, is the only one of the five variables which contributes significantly to the multiple regression. In other words, practically as much information can be obtained from this one variable as from all five together, as is shown by comparing the standard errors of estimate (table 5). This error amounts to 517.1 gm in the case of the single variable and to 497.4 gm when all five variables are utilized. In the Negro male group, the independent variables, stature and area of shaft, are each shown by the t test to be significant at the .02 level, whereas area of compact bone shows no more than a suggestion of contributing information to an estimate of skeleton weight ($.1 < P < .2$). In the White female series the area of compact bone is the only one of the independent variables which contributes significantly to the multiple regression. It is significant at the .001 level and provides an estimate of skeleton weight with a lower standard error of estimate (450.7 gm) than does the combination of all five independent variables (458.3 gm). And, in the Negro female series area of compact bone is significant at the .05 level but the variables, age and area of shaft, both contribute more significantly to the multiple regression. For each, the level of significance is shown by the t test to be at the .001 level.

Thus, the evidence provided by the independent variables tested in this study suggests that for American Whites of both sexes, the area of compact bone is the most efficient variable in estimating weight of the skeleton. For the females it provides an estimate with a lower standard error of estimate than when all five variables are contributing, and for the males the estimate based on this single variable has a standard error

TABLE 7

Regression equations for estimation (E) of skeleton weight (gm), with coefficients of correlation (r or R) and standard errors of estimate (gm)

INDEPENDENT VARIABLES	EQUATIONS	r	R	STANDARD ERROR OF ESTIMATE
				gm
	<i>White male</i>			
Area compact	$E = 93.8X_5 + 1621.3$	.6091		517.1
	<i>Negro male</i>			
Stature* and area shaft	$E = 28.1X_2 + 42.6X_4 - 2884.8$		.6247	654.3
	<i>White female</i>			
Area compact	$E = 73.2X_5 + 1578.7$	.7078		450.7
	<i>Negro female</i>			
Age, area shaft, area compact	$E = -13.6X_1 + 60.8X_4 + 29.5X_5 + 13.1$		.6864	469.7

* Stature in this study was taken on cadavers. It has been shown that cadaver stature according to the method used in this laboratory is 2.5 cm greater on the average than living stature (Trotter and Gleser, '52). In applying this formula to the living, adjustment should be made by adding 2.5 cm to living stature.

of estimate which is not reduced significantly from the estimate based on all five variables. For American Negroes area of compact bone is a less efficient variable for estimating weight of the skeleton than it is for Whites. For the Negro males the information provided by area of compact bone is exceeded by area of shaft and by stature, and for the Negro females by area of shaft and age. In the latter group area of compact bone contributes significant information also and

may be used in conjunction with age and area of shaft; however, when standard regression coefficients are recalculated on the basis of the information in age, area of shaft and area of compact (X_1 , X_4 and X_5) of the Negro female group the t test for $b'_{5.14}$ does not reach the .05 level of significance.

Equations. The variables shown by the t test to contribute significantly to the information provided by standard partial regression coefficients have been utilized in calculating regression equations for estimation of weight of the skeleton. They are presented in table 7 along with the correlation coefficients (r or R) and the standard errors of estimate. The probability of each single and multiple correlation coefficient is $< .001$. For the White male and female groups the equations are derived from the single variable, area of compact bone. For the Negro male group, stature and area of shaft are the variables involved. And, for the Negro female group the equation is calculated from the three variables, age, area of shaft, and area of compact bone, shown to be significant in table 6, even though area of compact does not reach the .05 level of significance when only these three variables are considered.

It may be noted that the standard error of estimate determined from the data using area of compact bone of the present series of White male skeletons is 517.1 gm as compared to 528.8 gm calculated for only the 24 skeletons of this series which comprised the material of the preliminary study.

DISCUSSION

In considering the aim and results of this study, the living body is viewed as a whole whose parts are interrelated during their development as well as during maturity and the declining years. The living skeleton is no exception. The weight of the skeleton, or any of its component parts, is the product of a complex of effects expressed in its size and composition. Of all the independent variables considered in this investigation femur weight is the most highly correlated with skeleton weight. From it could be derived a more precise estimate of

skeleton weight than from any of the other variables. However, the use of only those measurements which can be assessed reliably in the living individual necessarily precludes weight of the femur. But, the other characteristics of the femur, considered in this investigation, are expressions of its size and composition and may be determined from radiographs of the living. These are length, area of the middle half of the shaft and area of compact bone in the middle half of the shaft. Thus, it is found that certain characteristics of the femur provide information for reliable estimations of skeleton weight in living American Whites and Negroes of both sexes within certain ranges of variability.

The very nature of the material has placed certain limits on these ranges of variability. For example, racial background predisposes a skeleton to certain proportions; that is, a Negro may be expected to have limbs in which the forearm and leg are longer in relation to their immediately proximal segments than a White. On the other hand, a White may be expected to have shorter, more massive long limb bones than a Negro. Sex also places an individual within a certain reaction range, for it is anticipated that a female will have shorter, lighter and less rugged bones than a male of the same race.

Area of compact bone, per cent of compact bone and weights of femur and skeleton are variables which may be affected by environment and are subject to change during the life span, whereas stature, femur length and area of shaft are variables which are determined by the genetic constitution of the individual and change little, if at all, during adult life. In the present study it is not possible to determine to what extent intrinsic hereditary factors and to what extent extrinsic factors, such as aging and state of nutrition, are responsible for the range of individual measurements in either group of variables. It should be noted, however, that the effect of aging on stature and the change during successive decades in maximum adult stature of the American White and Negro population have been found to be small (Trotter and Gleser, '51a and b). It may be assumed that hereditary factors confer a poten-

tial with regard to size and weight of the skeleton or its component parts. The extent to which this potential is realized depends on environmental conditions. Trends with aging have been seen to occur in the former group of variables (area of compact bone, weights of femur and skeleton) which are no doubt more subject to the influences of environment than are the measures of size. The variables of the latter group (stature, femur length, area of shaft) may be expected to attain and remain at their potential levels of development.

The analyses of the data in this study indicate that the same variable does not provide the best information for estimation of skeleton weight in each sex and in each race under consideration. In the Whites of both sexes the variable, area of compact bone, which is one of the group affected by environmental conditions, plays the most significant role. But for the Negroes, area of shaft, an hereditary factor, is a better indicator; for the males this variable is best complemented by stature, another hereditary factor; and for the females by age and to only a minimum amount, by area of compact bone. The fact that area of compact bone may be considered at all as a reliable indicator of weight for the Negro females suggests a sex difference, which is supported by the greater significance of this variable in White females than in White males. It has a higher coefficient of correlation with skeleton weight in White females than in White males, and a probability of $< .001$ in the t test of standard partial regression coefficients of White females in contrast to $P < .01$ of White males.

SUMMARY AND CONCLUSIONS

A series of 204 skeletons was selected from the Terry Collection with approximately equal distribution among Whites and Negroes of both sexes and for each decade from early adulthood to old age. The cadaver stature was known. For each case the individual bones and the skeleton as a whole were weighed. Measurements were taken from radiographs of maximum femur length, area of the middle half of the

femur and area of compact bone in the middle half of the femur. These data were analyzed statistically, according to race and sex, in order to determine which variables, singly or in combination, could be used to derive equations for the most precise estimation of skeleton weight in the living.

Correlation coefficients and their standard errors of estimate were determined for certain independent variables with skeleton weight, the dependent variable. Of these, area of compact bone in the middle half of the femur provides the highest correlation coefficient with skeleton weight and the lowest standard error of estimate in White males, White females and in Negro females; for the Negro males, area of the middle half of the femur has the highest correlation coefficient with skeleton weight and the lowest standard error of estimate.

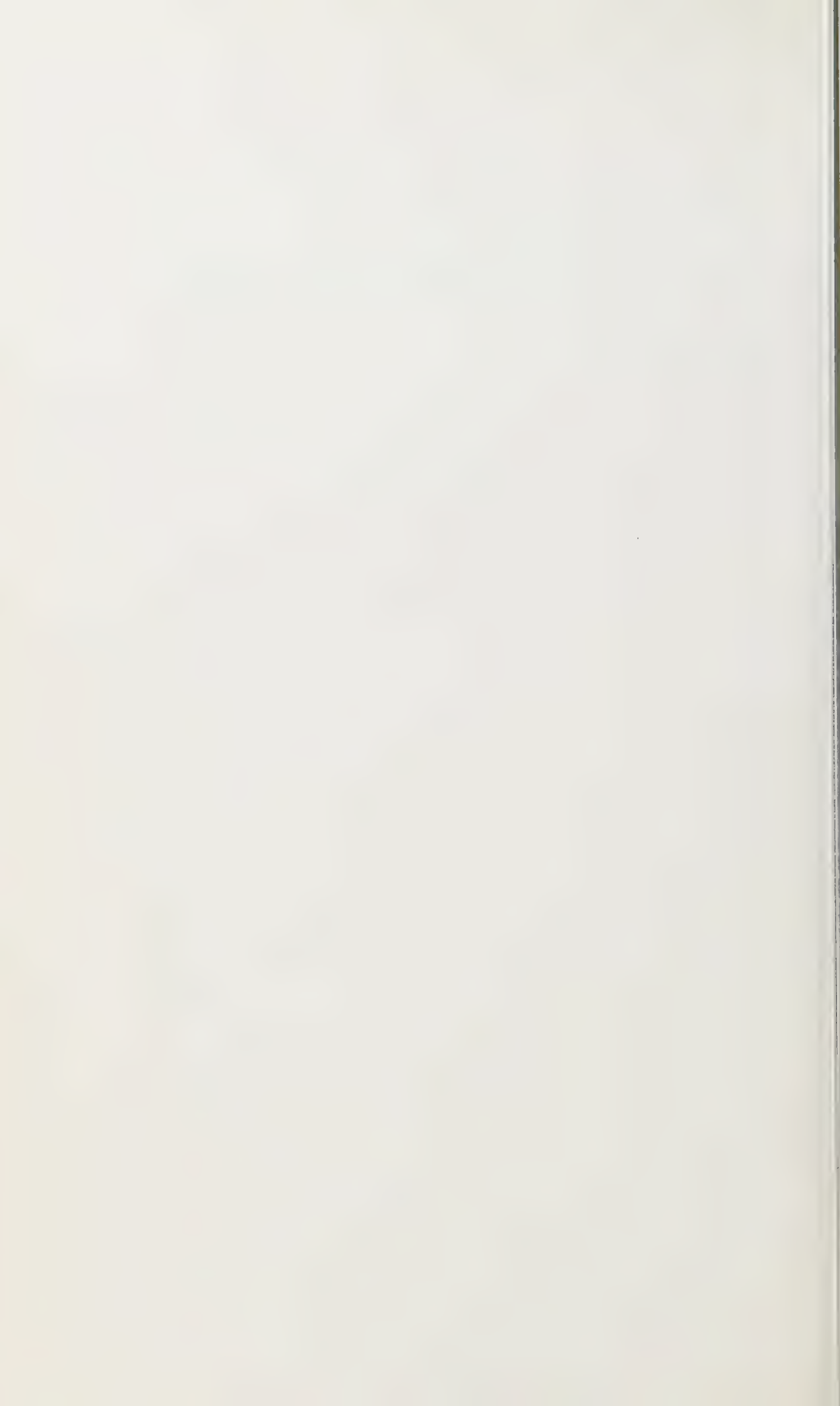
Systems of normal equations using the five variables, age, stature, femur length, area of shaft and area of compact bone, in relation to skeleton weight were solved for the standard partial regression coefficients. These coefficients were tested for significance and only those variables contributing significantly were used in regression equations for estimation of skeleton weight. The regression equations involve only the variable, area of compact bone, for both White male and female groups; stature and area of shaft for the Negro male group; and, age, area of shaft and area of compact bone for the Negro female group.

These equations may be used to estimate the weight of the dry, fat-free skeleton of the living in comparable samples of the population. In approximately two-thirds of cases there will be an error of as much as, or less than, the standard error of estimate.

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THE BASE OF THE SKULL IN IMMATURE HOMINIDS

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THREE FIGURES

INTRODUCTION

It is often said that the primate fossils known as the Australopithecinae carried their heads more like men than apes (Dart, '25; Broom, '38; Le Gros Clark, '50, '54). The primary justification for this belief is the contention that the foramen magnum and occipital condyles are relatively much further forward in these fossils than in the great apes. Dart ('25) noted this fact in his original description of *Australopithecus africanus*, and suggested that it indicated "... the assumption by this fossil group of an attitude appreciably more erect than that of modern anthropoids." Keith ('31), on the other hand, held that the position of the foramen magnum in the Taungs specimen was far more ape-like than human, and wrote that there was "... no reason for believing, on the evidence supplied by the skull, that the posture of Australopithecus differed from that of the young chimpanzee or gorilla." Later, however, when adult specimens of the Australopithecinae were discovered, Dart's original claims were reiterated by Broom ('38) who, in writing about an adult specimen of *Paranthropus robustus*, stated that the occipital condyle was further forwards than in the chimpanzee and gorilla, and that this "... appears to indicate that the ape walked somewhat more erect than the living anthropoids." Few of the Australopithecine fossils, however, have the base of the skull intact, and practically no measurements have

been provided in support of the general statement. Of those that are available, the most important relates to the fossil known as *Plesianthropus V*, in which, according to Le Gros Clark ('50), the ratio of the post- to pre-condylar segments of the skull when orientated in the Frankfurt plane is about 40%. Le Gros Clark's observations suggested that this value was equalled by only one gorilla ". . . of very unusual (? abnormal) shape in the British Museum collection." He did not, however, provide any figures to show what the value of the index was in human skulls. In a more extensive comparative study, Ashton and Zuckerman ('51, '52) found that the index relating to the post- and pre-condylar segments in *Plesianthropus V* approximated closely to that for existing apes and monkeys, and that it was very different from the values of the index for extant and fossil men.

The base of the skull is intact in the immature fossil specimen S.K.47, which has been assigned to the species *Paranthropus crassidens*. This specimen is described as follows (Broom and Robinson, '52): ". . . it has the lower part of the occipital scarcely at all crushed, and the palate is nearly perfect. The middle region of the base is fairly well preserved, but considerably crushed." As a cast of this specimen was available in the British Museum (Natural History), it seemed worth enquiring whether it shed any light on the way in which the skull was poised on the vertebral column. In the present study it has been compared with chimpanzee, gorilla and human skulls of corresponding age.

MATERIAL AND METHODS

S.K.47. The measurements which Broom (Broom and Robinson, '52) gives of the original specimen of *Paranthropus*, S.K.47, agree to within 1 mm with those of the cast, which provides a very clear impression of the planum nuchale of the occipital bone, of the mastoid region of the temporal bone, and also of the palatal surface of the upper jaw. The foramen

magnum and occipital condyles are intact, as is also the basi-occipital bone. It is difficult, however, to see in which way the crushing affected the articulation of the latter with the basisphenoid, or the way in which the basisphenoid and pterygoid laminae were crushed. All that is obvious is that the relative disposition of the planes of the palate, foramen magnum and planum nuchale will have been affected; and that the crushing may have altered the length of the pre-condylar segment without affecting that of the post-condylar segment of the skull. It is also clear from the cast that the posterior part of the skull has been distorted. The inion is now to the right of the midline, and the right mastoid process is more anterior than the left.

The first and second permanent molars are in place on the right-hand side, and the second premolar is erupting. The palate and the shape of the palatal arch in the fossil appear more human than the corresponding features in either gorillas or chimpanzees of similar age.

According to the description provided by Broom and Robinson, the three tooth sockets which are preserved anterior to the erupting premolars contained the permanent canines and permanent incisors. The cast does not permit one to see this, and while it is highly improbable that the permanent incisors would not have erupted by the time the second molars had appeared, and by the time the second premolar was about to erupt, it is not entirely clear why it is assumed that the first premolars and the permanent canines had already erupted. This point has been referred to elsewhere (Clements and Zuckerman, '53).

Comparative material. Comparisons were made with as many ape and human skulls of corresponding age as could be conveniently obtained. Fourteen chimpanzees and 16 gorillas belonging to the Powell-Cotton Museum, Birchington, were studied. In all these skulls the first permanent molars and permanent incisors had erupted, and the second permanent molars were present, either alone or in conjunction with one

or both premolars. Neither the canines nor the third molars had appeared in any skulls of the series.

A total of 21 immature human skulls of unknown modern stock were studied. All were from the Departments of Anatomy of Birmingham and Cambridge Universities. In each skull of this series, the incisors, first molars, and one or more teeth from the group comprising the canines, premolars and second molars, had erupted. The third molar had not appeared in any skulls of the series.

Nature of examination. On each skull the general size, shape and disposition of the planum nuchale were studied, attention being paid to the development of the external occipital crest, and the prominence of the muscular markings on the squamous part of the occipital bone. In addition, notes were made of the size and shape of the mastoid process and of the configuration of the digastric groove. Rough quantitative estimates were made of the size and shape of the planum nuchale. For this purpose measurements were made of the distance between the opisthion and inion, and the opisthion and the highest point on the arch of the superior nuchal line, the width between the most lateral points of the superior nuchal lines, and of the width between the lateral limits of the jugular notches.

The position of the foramen magnum relative to the anterior and posterior extremities of the fossil could not be defined with the skull orientated along the Frankfurt horizontal. For the purpose of the present study the line joining the prosthion and opisthocranion was divided by a perpendicular drawn from the mid-point of the occipital condyles, and an estimate made of the ratio of the posterior and anterior segments.

The relative inclination of the foramen magnum (as defined by the line joining the endobasion and opisthion), and the planum nuchale (as defined by the line joining the opisthion and inion) were measured on craniometric tracings.

RESULTS

The planum nuchale

Shape and size (table 1 and plate 1). The planum nuchale of the occipital squama of *Paranthropus crassidens* S.K.47 appears far more ape-like than human. It forms a relatively flat surface and its antero-posterior and transverse dimensions are very similar to the average for the chimpanzee. On the other hand, the former are greater, and one of the latter smaller than in modern man. Although similar in shape, the planum nuchale in the fossil is smaller than in the gorilla.

Muscular markings (plate 1). The muscular markings of the occipital region of the fossil are far more pronounced than in either man or the chimpanzee, and are as well developed as in gorillas of corresponding age.

Nuchal lines. The superior nuchal line of *Paranthropus crassidens* is clearly defined and is undamaged on the right side of the fossil. The inferior nuchal line is far less distinct, but the areas to which the *semispinalis capitis*, *rectus capitis posterior minor*, *rectus capitis posterior major*, and *obliquus capitis superior*, were attached can be made out easily. The supramastoid region bulges laterally above what appears to be the upper limit of attachment of the *sternomastoideus* and *splenius capitis*, and as far as can be made out from the cast, what appears to be the inferior temporal line is present in this region on the left-hand side, separated from the superior nuchal line by approximately 5 mm. This anatomical diagnosis is not absolutely certain, since the bone is broken off 2 or 3 mm above this line.

In gorillas of corresponding dental age, but not in chimpanzees, the superior temporal and nuchal lines would have "met" for a short distance mid-way between the supramastoid region and the inion, to form the beginning of the nuchal crest. According to Weidenreich ('40), the crest is actually formed over a region of thickened bone which he calls the torus occipitalis. In the gorilla this torus continues into the supramastoid region, which bulges relatively more than in

TABLE 1

Some quantitative features of Paranthropus crassidens, the apes, and man (95% of the population of apes or men would be expected to lie between the upper and lower 95% fiducial limits)

Overall dimensions of planum nuchale — Measurements in mm

	INION-OPISTHION			HIGHEST POINT OF NUCHAL LINE — OPISTHION		
	Chimpanzee	Gorilla	Man	Chimpanzee	Gorilla	Man
Mean	32.9	44.5	26.8	37.9	50.4	34.1
No. of observations	14	16	21	14	15	21
S.E. of mean	0.63	1.31	0.66	0.85	1.39	0.98
95% fiducial limits	38.1	55.7	33.1	44.8	61.9	43.5
	27.8	33.3	20.5	31.0	38.8	24.7

Overall dimensions of planum nuchale — Measurements in mm

	WIDTH BETWEEN MOST LATERAL POINTS ON NUCHAL LINES			WIDTH BETWEEN LATERAL BORDER OF JUGULAR NOTCHES		
	Chimpanzee	Gorilla	Man	Chimpanzee	Gorilla	Man
Mean	106.2	126.5	107.7	49.5	57.9	65.5
No. of observations	14	15	21	14	15	21
S.E. of mean	1.53	1.61	0.82	0.75	0.78	0.61
95% fiducial limits	118.5	139.9	115.5	55.5	64.5	71.3
	93.8	113.5	99.8	43.4	51.4	59.6

Overall dimensions of planum nuchale — Measurements in mm

	CONDYLE-OPISTHOCRANION × 100/CONDYLE-PROSTHION			ANGLE BETWEEN FORAMEN MAGNUM AND NUCHAL PLANE		
	Chimpanzee	Gorilla	Man	Chimpanzee	Gorilla	Man
Mean	45.0	41.6	99.9	137.4	138.5	148.0
No. of observations	14	16	21	14	16	21
S.E. of mean	0.92	0.99	1.80	1.62	1.61	1.64
95% fiducial limits	52.4	50.0	117.1	150.5	152.2	163.7
	37.6	33.2	82.7	124.3	124.8	132.3

Paranthropus. In these characters the fossil differs from gorillas of corresponding age, but agrees with the chimpanzee.

In young human skulls, the superior nuchal line is far less pronounced than in S.K.47 and the overlying bone is not thickened even in the supramastoid region.

Inion and external occipital crest (plate 2). The inion of S.K.47 projects downwards and backwards as a sharp process which continues into a prominent external occipital crest. The latter fades out 1 cm from the opisthion.

The inion and external occipital crest of the adolescent gorilla and chimpanzee are, in general, less well marked than in the fossil. In the few apes in which a crest was found, it was most marked between the opisthion and the inferior nuchal line.

In several immature human skulls the external occipital crest is well developed, but, as in the apes, and in contrast to *Paranthropus*, it is the anterior part which is most pronounced. At this dental age the inion is much less prominent than in S.K.47, and is often absent.

Mastoid process (plate 3). The mastoid processes of S.K.47 are small and pointed, but project as true processes. Their medial surface is convex. Mastoid processes of similar size are found in most male and female gorillas of comparable dental age. In some individuals they are broader and more bulbous. In others they are just as compressed from side to side as in the fossil. In immature chimpanzees, on the other hand, there is usually no distinct mastoid process. In those exceptional specimens in which it is present, the process is much smaller, and more bulbous than in S.K.47.

In human skulls of comparable dental age the mastoid processes are usually bigger and more compressed from side to side than in the immature *Paranthropus*.

Digastric groove (plate 1). In S.K.47 the mastoid process bounds a sharp digastric groove. Medial to this and running parallel to its anterior half is a separate and well-marked groove — apparently for the occipital artery. In gorillas and

chimpanzees of corresponding dental age the digastric groove is usually much broader and shallower than in the fossil, and there is seldom a separate groove for the occipital artery. In man the digastric grooves are, on the average, much deeper and narrower than in the apes. In many specimens they are deeper and narrower than in the fossil, and there is usually a separate groove for the occipital artery. In most human skulls, and in contrast to the fossil, this runs parallel to the digastric groove for most of its length.

The position of the foramen magnum (table 1 and plate 1). The pre-condylar segment of the base of the skull, as measured by the index noted on page 614 is relatively much shorter in man than in the chimpanzee and gorilla. In the fossil the index falls between the mean values for man and for the two apes; it is outside the ranges of variation of all three, but lies closest to the mean values for the ape skulls. It is difficult to tell from the cast what effect the crushing of the fossil would have had on the value of the index. The dimensions of the segment posterior to the occipital condyles have been little, if at all, affected, whereas it would seem that the anterior segment would have been decreased, rather than increased, by the crushing which has obviously smashed and compressed the pterygoid processes and apparently the posterior part of the palate as well.

The angulation of the foramen magnum and planum nuchale (table 1 and plate 3). The angle between the plane of the foramen magnum and the planum nuchale is much more open in *Paranthropus* than in the apes, and in most of the human skulls that were studied. The angle may, however, have been increased by the distortion which has clearly affected the anterior part of the occipital squama.

The relative positions of the occipital condyles and mastoid processes (plate 1). In adolescent apes the line joining the tips of the mastoid processes usually passes through, and in men of corresponding age slightly behind, the middle of the occipital condyles. In *Paranthropus* it passes completely behind the condyles themselves. This difference between the fossil

and modern hominoids may have some anatomical significance; it is more likely that it is another result of distortion.

DISCUSSION

Because of the crushing of its middle part, S.K.47, which appears to give a faithful picture of so many anatomical features, unfortunately fails to provide a clear answer to some of the more important questions which it invites. It is obviously far more simian than human in its general appearance, but several of its characters appear to stand on their own.

The ratio of the posterior to the anterior part of the opisthocranion-prosthion diameter, although more ape-like than human, does not fall as closely into the range of observations for apes as does the corresponding condylar-position index in *Plesianthropus V*. On the other hand, the growth of the skull in all Old-world Primates is associated with a backward movement of the foramen magnum relative to the base of the skull. This fact is derived mainly from indices in which an internal or external measurement of the antero-posterior dimension of the brain case has been taken as the baseline (e.g. Bolk, '09). Since the eruption of the permanent teeth is associated with an increase in the prognathism of the skull, it would be expected that the "backward migration" of the foramen magnum would appear more conspicuous if expressed in terms of a ratio that uses the opisthocranion-prosthion diameter as a base-line. Moreover, because of differences in degrees of prognathism, it would also be expected that the value of the index in apes would decrease relatively very much more during growth than in man (a point which has been confirmed in a preliminary study). Since the Australopithecinae were scarcely less prognathous than chimpanzees, it is, therefore, reasonable to suppose that the index expressing the position of the occipital condyles in S.K.47 would have approximated relatively far more to that of the great apes had the creature lived until it was mature. Had it done so, it is difficult to believe, too, that it would not have grown a prominent nuchal crest, and one at least as pronounced as

occurs in the adult specimens of *Paranthropus crassidens*, S.K.48 and 49. Such a conclusion would be far more in keeping with the simian appearance of the planum nuchale, and its powerful muscular markings and prominent superior nuchal line, than any alternative proposition.

SUMMARY

1. A cast of an immature specimen of *Paranthropus crassidens* (S.K.47) has been compared with chimpanzees, gorillas and men of a corresponding age.

2. The planum nuchale of the occipital bone of *Paranthropus* is similar in size and shape to that of the chimpanzee, but differs from that in man.

3. The muscular markings of the occipital region are more pronounced than in man, but not more so than in the gorilla.

4. The contours of the superior nuchal line of S.K.47 resemble those of the chimpanzee rather than the gorilla or man.

5. The external occipital crest of the fossil is more pronounced than in apes and men of a corresponding age. It differs from both in that its posterior part is developed more strongly than the anterior.

6. The mastoid processes of S.K.47 are most like those of the gorilla, although differences occur between their digastric grooves.

7. The occipital condyles are placed more anteriorly than in the apes, but are, nevertheless, closer to the average position in apes than in man.

8. The angle between the foramen magnum and planum nuchale is bigger in S.K.47 than in either apes or man.

9. It is submitted that this fossil does not provide conclusive evidence of how the Australopithecine skull was poised.

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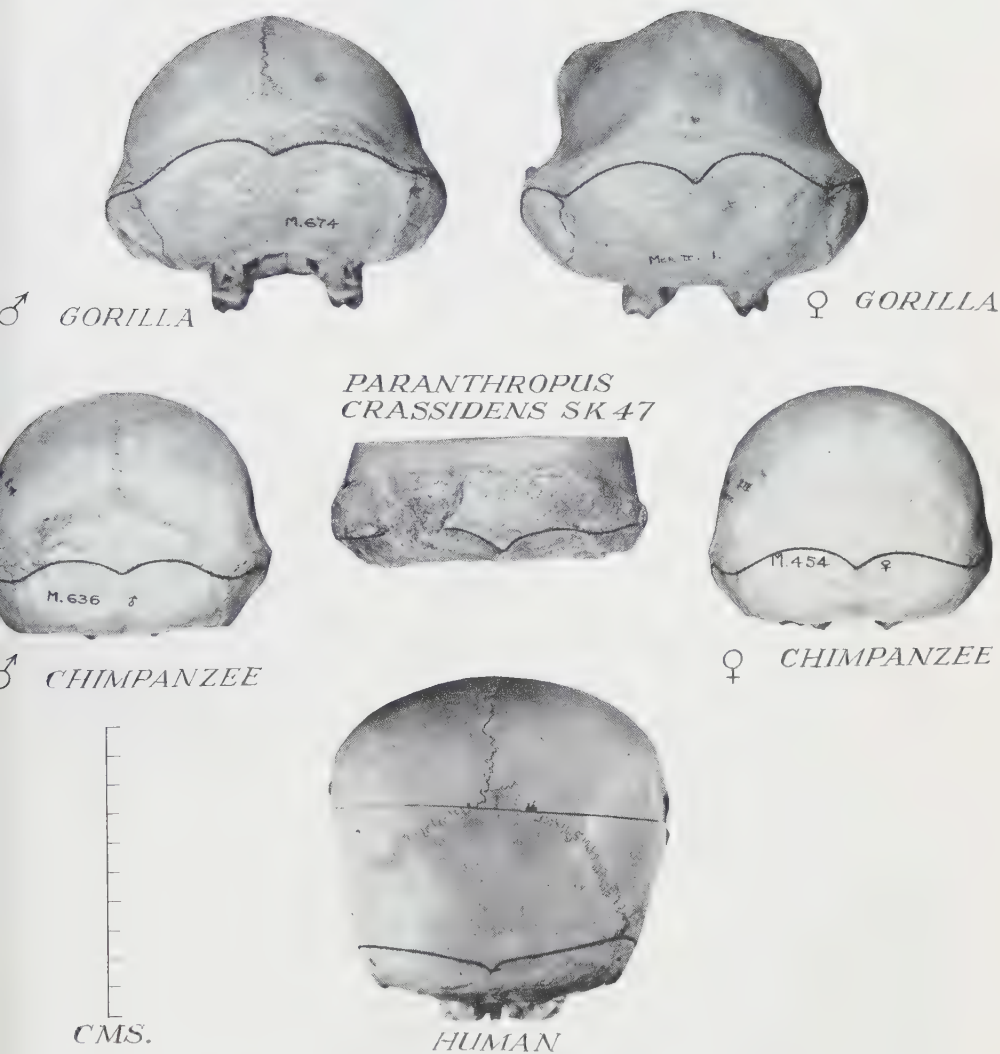
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PLATES 1-3

Comparison between *Paranthropus crassidens*, immature apes and man.

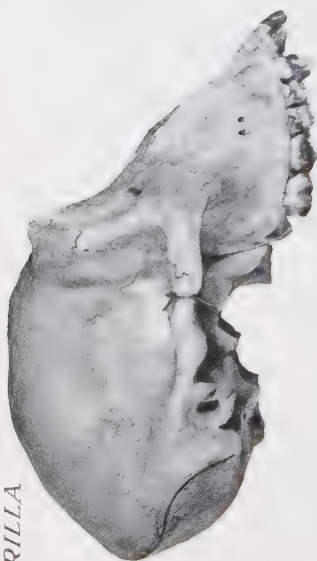


1 Skulls viewed at right-angles to plane of foramen magnum.



2 Skulls viewed parallel to plane of foramen magnum.

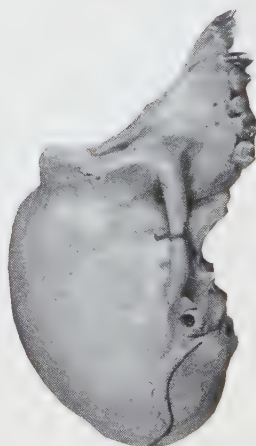
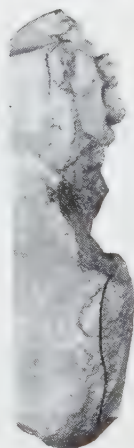
♂ *GORILLA*



♀ *GORILLA*

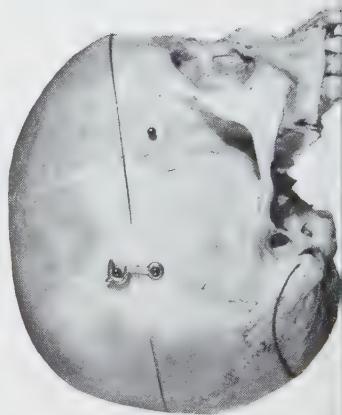
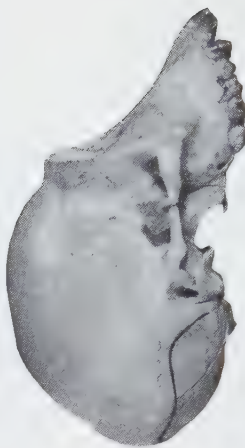


PARANTHROPUS
CRASSIDENS SK 47



♂ *CHIMPANZEE*

♀ *CHIMPANZEE*



MORPHOGENETIC STUDIES OF THE RABBIT

XVI. QUANTITATIVE RACIAL DIFFERENCES IN OSSIFICATION PATTERN OF THE VERTEBRAE OF EMBRYOS AS AN APPROACH TO BASIC PRINCIPLES OF MAMMALIAN GROWTH ¹

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TWO FIGURES

INTRODUCTION

The literature dealing with various aspects of growth and body form of man and his laboratory and domestic animals reveals increasing tendency to shift from purely descriptive and quantitative investigations to an analytical strategy, with emphasis on theory and experiment, and attention focused upon the specific processes involved (Washburn, '53; Zuckerman, '50). The morphologist is becoming increasingly aware that the significance of his results depends upon how well his measurements can be related to functions or processes going on within the developing organism (Young, '50). In general, it is conceded that observed differences in form and proportion among both *fossil* and *living* forms are the result of changes in the rate of growth of parts in relation to each other.

Genetically, clear evidence of unit specificity for either morphological units or growth processes is available for

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relatively a limited number of characteristics. Such genes as are known to induce large and specific effects lead to gross abnormalities. They have contributed much to knowledge of the physiology of the gene action involved (for example, Bateman, '54), but thus far they have contributed little to the problems involving the more subtle differences of type, conformation, and body build, so important to the anthropologist, clinician, and student of breed improvement. The major proportion of growth differences seem to be affected by numerous genetic and environmental influences (Dickerson, '54). The quantitative studies of size and variability of whole individuals or parts in succeeding generations have been useful in supplying estimates of the relative effects of genetic vs. environmental influences upon a population; of the number of genes involved in crosses of races of different body size; and of the relative degree of genetic homogeneity which has been achieved by a particular method of breeding. To the zoologist and geneticist, evolution has become a history of genetic systems. Changes in isolated populations are now recognized as the result of mutation, selection, and accidents of genetic sampling (random drift). Applied to type and conformation the major cause of any permanent population change would be selection (either naturally or under human control) of those growth differences which are genetic.

It seems remarkable that in spite of the fact that the comparative tradition is so deeply embedded in the science of embryology, there has been very little detailed comparison of developmental processes in related forms directed towards discovering *the genetic nature of growth processes* or towards analysis of the species or racial differences between them. As Young ('50) has pointed out, some effort has been made in related amphibians and species of *Drosophila*, but we still have relatively little knowledge about the way in which, for example, uniformly rhythmical metameric systems (such as the vertebrae or teeth) become broken up into a series of diverse parts. Nor do we know specifically what happens when vertebrae at the border of one regional level (thoracic,

for example) become modified to resemble vertebrae of the adjacent region.

This is particularly surprising, since as early as 1908 Minot directed attention to the processes which in the course of development find expression as growth, differentiation, decay, and death, thereby laying a theoretical background for the study of size and conformation as it varies with age. Later Thompson ('16) drew attention to the formal unity and coherence in the structural relationships between animals by bringing their outward shape into the domain of mathematical inquiry.

Subsequent efforts along these lines have been primarily focused almost exclusively on the empirical formulations developed by Thompson with reference to evolutionary trends and on the techniques demonstrating the constant differential growth ratios described by Huxley ('32). This recognition of the importance of differential growth as a mechanism of evolutionary change was very useful. It stimulated the development of mathematical techniques for the treatment of quantitative data and helped in determining certain general laws of growth which could be inferred from observed regularities in size shifts (i.e., gradients, genetic fields, etc.) as affecting form and proportion; however, as pointed out by Baer ('54), it has not yet indicated just how these shifts come about. The utility of inferences about morphological changes derived from application of the mathematical approach without adequate regard for the biological processes of growth and analysis of the causal factors involved has been questioned by Waddington ('50), Young ('50), and Washburn ('53).

A question fundamental to all studies of growth would seem to be: to what extent can the observed phenomena submitted to experimental or mathematical test represent either measures of discrete morphological elements, functional systems, or any other true units of growth? If the measurements are to represent growth changes then an understanding of the growth processes is necessary as a basis of mensuration.

A substantial experimental foundation has already been laid for the identification and study of the growth processes of the skull. DeBeer ('37), Stockard ('41), Weidenreich ('41, '45), Washburn ('47), Brodie ('41), and a number of others have made valuable contributions. Vital stains, gene induced pathologies, the split-line phenomena (Benninghof, '25) and various sorts of surgical and mechanical manipulations are techniques which have been used. Most recent, and perhaps most significant, are those of Bateman ('54) on the mouse, and Baer ('54) on the rat. Bateman has studied the entire skeleton as well as the skull, including the axial and appendicular skeleton, making use of two lethal mutants (gray-lethal and microphthalmia). This technique was also applied earlier by others, notably Weidenreich and DeBeer. He has considered the growth processes as they affect each bone independently of the rest, and in terms of the well defined processes of accretion and erosion at normally visible surfaces. This appears to offer certain advantages in differentiating intrinsic and extrinsic factors in bone development, and Bateman has rendered a most valuable service in focusing attention upon these very basic processes and their activity in the development of individual bones. However, it is the intrinsic pattern of growth over a much broader area than any one skeletal unit which may be of greatest significance in exposing the true biological nature of growth processes. Of this Bateman is obviously aware, since in one of his closing statements he says: "In short, it is probable that the inherent determination (bone growth) is not of local growth processes but of whole patterns of growth."

Baer, who used the technique of vital staining on the rat, concludes, after discussion of the literature, that increase in the size of the skull is a result of two growth processes: (1) changes in diameter of individual bones, and (2) size increase between bones with continuous surface apposition and resorption, the pattern of which is primarily influenced by two basic systems of growth: (a) early rapid expansion of the brain case in conjunction with brain growth, and (b)

slow growth of longer duration which elongates the base and face. He thus not only recognized mechanical pressures and other processes affecting individual bones, but also the broader localized influence exerted over a complex of skeletal units.

This breadth of localized genetic influence is a phenomenon which has been recognized for some time in studies attempting to analyze the genetic background of certain internal variations such as supernumerary skeletal parts (ribs, presacral vertebrae, sternebrae) summarized by Peck and Sawin ('50). In invertebrates such homoeotic variations are recognized and are determined by single gene mutations (Goldschmidt, '40; Villet, '42). Their manner of development, and ways in which they can be modified by environmental influence, are discussed in a series of papers: Villet ('42, '43, '44) and Goldschmidt ('40). In vertebrates they have been studied in man by Kühne ('31), Schultz ('38), and others; in the domestic fowl by Promptoff ('28); in swine by Shaw ('29), PerTuff and Berge ('36); in the mouse by Green ('41, '54); and in the rabbit by Sawin et al. (see Peck and Sawin, '50, for summary). A simple and clearcut Mendelian interpretation for homoeotic variations in individual units such as occurs in invertebrates has in no case been established, and the modifying influences of maternal and other environmental influences are recognized and have been studied by Green and others. Most if not all recognize the genetic background as playing a major role, however. Evidence that this background is broadly associated with groups rather than individual vertebrae was presented by Sawin and Dietz ('50), and Tanner and Sawin ('53), and evidence that these same regional differences are manifest at the time of first ossification of neural arches and centra in embryos of 21 days has been shown by Cray and Sawin ('55).

The present paper describes the quantitative manifestations of these racial differences in ossification pattern of the vertebrae as observed in embryos of 21 days gestation as it has progressed both linearly and laterally. It discusses

them in terms of their genetic backgrounds and as possible tools in analysis of principles of mammalian growth which may be applied to both man and his domestic animals.

MATERIALS AND METHODS

Study has been made of the ossification patterns of the axial skeleton of 219 embryos of the same races of rabbits (III and X), described for incidence of neural arch and centra ossification centers by Crary and Sawin ('55). It also includes 52 embryos of race IIIc, a subline of III separated genetically by approximately 16 generations of close breeding. For brevity, race III, subline IIIc, and race X are referred to below only as races. These races have contributed previously to a number of investigations (by various authors) of morphological variations in newborn and adults leading to a concept of the existence of certain localized differences in growth and development between these races. For references see Peck and Sawin ('50). All embryos were taken by Caesarean section within ± 10 minutes of exactly 21 days postcopulation.

It is of particular interest that races III and X are of unlike general body size (race III mean adult body weight 3900 gm; race X 2200 gm); whereas races III and IIIc (4000 gm) are approximately the same. Whereas any regional differences which may occur between races III and X might conceivably be considered indirectly the result of general size differences, differences between III and IIIc could not, both being of the same origin and size. As has been shown by Peck and Sawin ('50), based upon certain qualitative characters (extra ribs and presacral vertebrae, ventral spinous processes, sternbrae, etc.) used as landmarks, and upon quantitative measurements of vertebral units (Tanner and Sawin, '53), race III (both lines) is regionally enlarged in the lumbar region, whereas race X tends to be enlarged in the cervico-thoracic region.

Race III, originally bred selectively for a maximum incidence of extra or 13th pair of ribs and an extra or 27th

presacral vertebra, has been maintained at approximately 95% of this type. Race X, selected for normal numbers of ribs and presacral vertebrae, produces about 17% which manifest one or both extra elements (most frequently the vertebra). Race IIIc, which is less inbred than III but similarly selected, also shows a greater range of variation, having 58.6% extra ribs and 22.9% extra presacral vertebrae.

In this investigation three measures of vertebral development are employed: (1) incidence of ossification centers for the paired neural arches and centra of each of the first 29-30 vertebrae, (2) the mean length of the centra of each vertebra, and (3) the mean width. Because not all centra are ossified at this stage, and the exact time of initiation of ossification is not known, the width and length data cannot be considered to give a precise estimate of growth rate. It is believed, however, that what is lost through this deficiency at this time is compensated by information with reference to the time of onset of the visible ossification process, and that more complete and precise information with regard to the growth processes themselves must come from extension of the study into earlier and later stages.

Operated mothers were remated at the first subsequent estrous, usually in 1-3 weeks. As many as 5 litters have been obtained from one mother, but invariably the number derived per mating declines in later litters. The embryos were routinely fixed for 15 minutes in formalin-aceto-alcohol fixative, weighed, skinned, and eviscerated, cleared with 1% KOH, stained with alizarin and stored in alcohol and glycerine, a modification of the method described by Cumley, Crow and Griffin ('39). They were studied with the aid of a binocular dissecting microscope using a 9 \times ocular and 1 \times objective, and measurements were made to the nearest 0.05 mm with a calibrated ocular micrometer (1 unit equalling 0.1 mm).

OBSERVATIONS

The patterns of ossification for races III and X, insofar as incidence of centra at 21 days is concerned, were presented

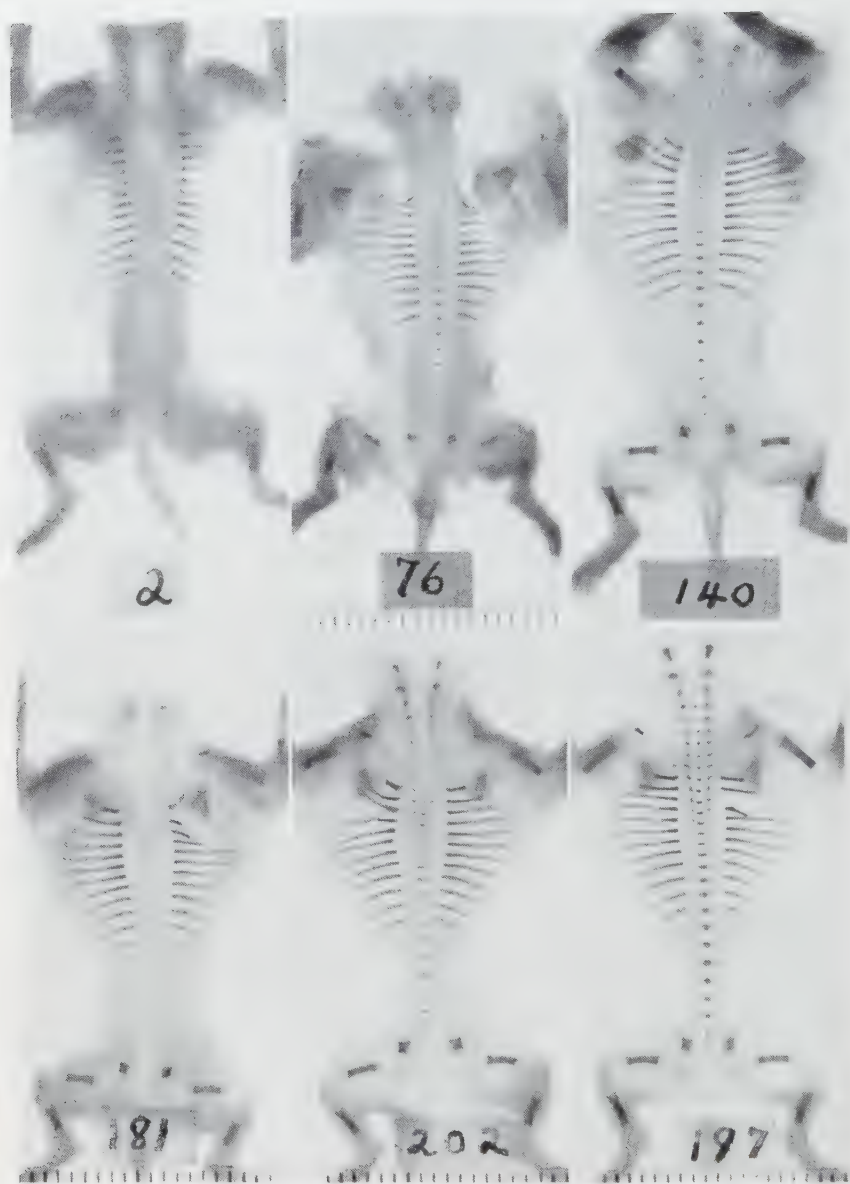


Fig. 1 Shows the range of variation in centers of ossification in race III (top) and IIIc (bottom) at 21 days, minimum ossification at left, maximum at right, average in center. For comparative range in races III and X at 21 days refer to Cary and Sawin ('55). Note bilateral bipartite centers of the centra in the thoracic region especially in embryos 140, 202, and 197, and those in tandem in vertebrae 19, 20, and 21 of embryo 202. See page 642 of text.

and discussed by Crary and Sawin ('55) and will not be elaborated on here except for comparative purposes (see figs. 2A and 2B). The significant new observations are the quantitative measurements in length and width of centra and the differences in pattern between races IIIc and III.

Range of variation

The range of variation in races III and IIIc at 21 days is shown in figure 1. It will be seen that in IIIc in both extremes and the average the amount of ossification is advanced over that of its parent race III. The minimum, exemplified by embryo 181, shows two regions of neural arch ossification, anterior cervical and cervico-thoracic, and centra ossification is just initiated on vertebra 15. In embryo 202 (average) ossification of neural arches is delayed in mid-thoracic and is well established in the centra of thoracic and lumbar regions. It is just being initiated in the mid-cervical. In 197, with maximum ossification, both neural arches and centra are well established in all but the very anterior cervical and sacro-caudal regions. Not only is ossification advanced, but one gains the impression that in general it appears to be centered more anteriorly than in either race III or race X.

Incidence of vertebral ossification centers at 21 days

The racial differences in manifestation of ossification centers are shown in figure 2 (neural arches fig. 2A and centra fig. 2B). The patterns of incidence of both neural arch and centra development of IIIc tend to conform to the same basic pattern for these centers observed in races III and X, i.e., consisting of three distinct areas of greater incidence of ossification (cervical, thoracic, and thoracolumbar) separated by two areas in which ossification lags (figs. 2A and 2B). They differ in two ways, however, both quite unexpected in view of the fact of the common origin of the two race III sublines. First, and most significant, is the fact that race IIIc is so much more precocious in its pattern

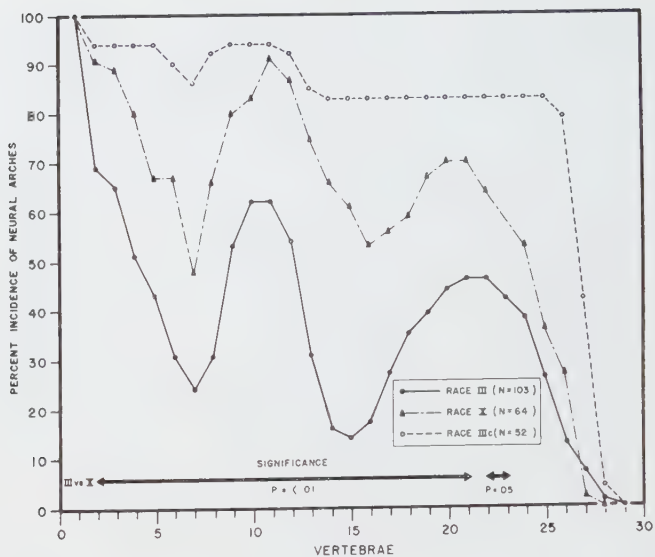


Figure 2A

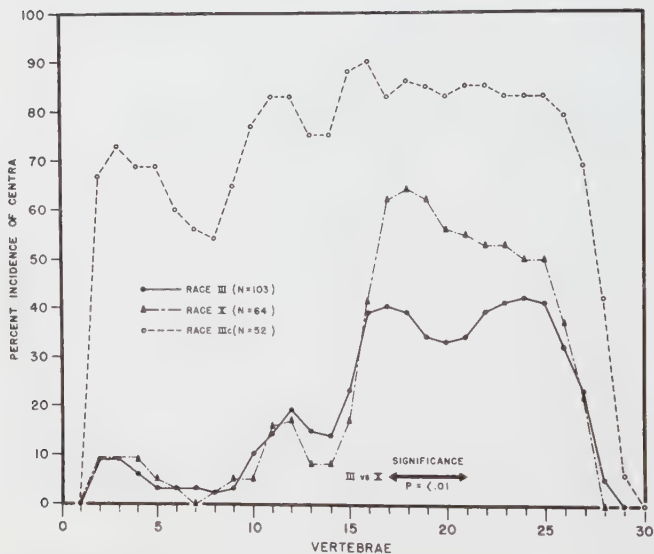


Figure 2B

Fig. 2 Shows incidence of vertebral centers of ossification of vertebrae 1-30 in races III, IIIc, and X (A, neural arches and B, centra) and their mean length (C.) and width (D.), with significance for each vertebra III vs X and III vs IIIc.

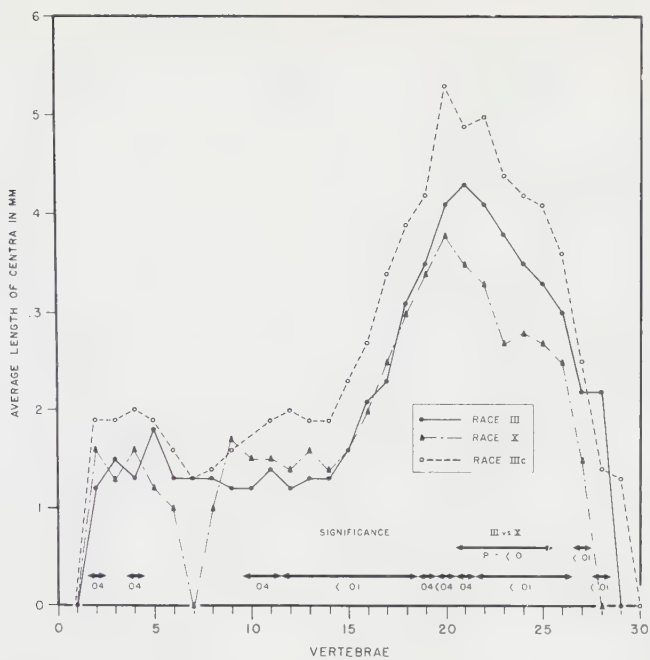


Figure 2C

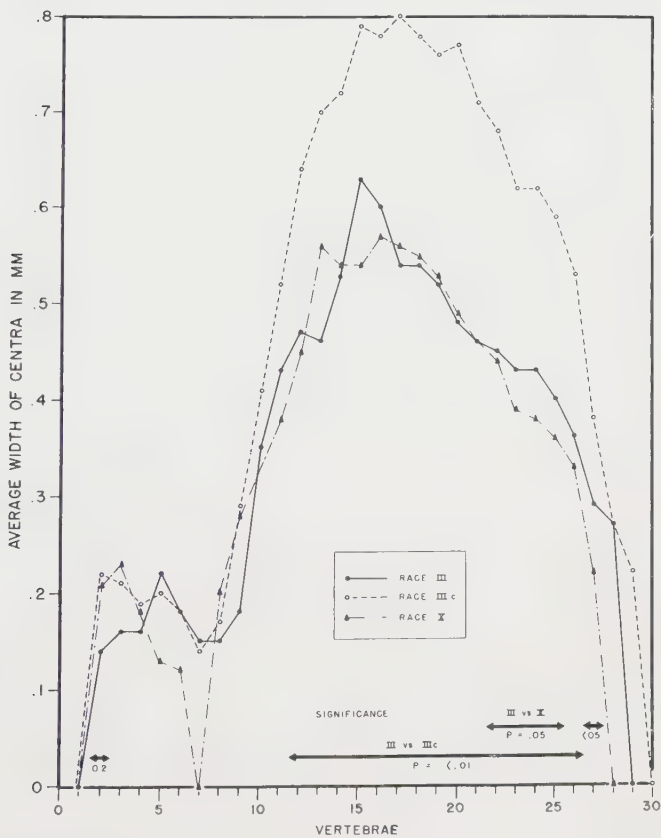


Figure 2D

of ossification than either III or X. Whereas III relative to small sized race X is significantly retarded, X is equally retarded when compared with IIIc, some of the centra of which average as much as 51% greater in incidence. Because at some stage of development all centers must become ossified, a stage here being rapidly approached, the fact that the pattern at this time in IIIc is much smoother with relatively smaller regional differences with respect to the peaks and valleys is probably to be expected. Both observations imply the existence of real differences in the rate of appearance of these centers at this time as well as an earlier onset. The second difference is that the incidence of centers of IIIc, both neural arches and centra, is greater in relation to those of the other races in the anterior region, indicating that not only is race IIIc more precocious in ossification but this precocity also is localized somewhat more anteriorly. Some additional genetic influence not found in III appears to have arisen in this subline which is not entirely general, but highly localized in its effect.

Since new centers of ossification seem to be initiated under conditions of retarded growth (see Crary and Sawin, '55), the consideration of the incidence of ossification centers at this stage leads to one of two conclusions, either that the rate of growth is slowest in IIIc, and proportionally greater in X and III in that order, or that a certain temporary retardation necessary to the onset of ossification has occurred earlier in race IIIc than in other races. It is of interest, therefore, to determine quantitatively whether there is an actual difference in the size of these skeletal units at this time, and whether the pattern of differences in size corresponds with the patterns of differences in incidence, and further the nature of changes in pattern during a definite interval of time.

Quantitative measurements of ossification centers

Because of the irregularity in shape and angulation of the neural arches, it has not proved practical to attempt to meas-

ure those centers in this material. The length and width of centra are shown in figures 2C and 2D.

Race III (fig. 2C) shows a significantly greater length over race X only on vertebrae 21-25 and 27. The fact that the mean length of centra is sometimes greater in race X than in race III, and sometimes less, is most interesting, indicating that although race X is precocious in the number of centra ossified at this time, it is lagging significantly in some areas in the rate at which growth in length is progressing, and that the two characteristics are in some way independent of each other. The centers of race IIIc, however, are significantly longer than those of III on vertebrae 2, 4, 10 to 26, and 28, most of them at the one per cent level.

Thus, the differences in lengthwise ossification of centra indicate that there is actually a greater difference between the growth rates of the two sublimes of race III than between the two races III and X, particularly in the thoraco-lumbar region. It is of especial significance that the cervical and the first few thoracic vertebrae tend to be closely similar in all races. This will be referred to later.

As shown in figure 2D, ossification must be proceeding laterally in the centra more rapidly than it is lengthwise in all three races. But whereas the differences between races III and X are significant only on vertebrae 22-25, between races III and IIIc, those on vertebrae 2 and 12-26 are highly significant, and proportionately are much greater in width than in the length. These significant differences in the thoraco-lumbar region are in marked contrast to those anteriorly in the cervical and anterior thoracic regions which are closely parallel and relatively retarded. Although the differences in width of the centra at this time tend to be in the same direction, the difference in rate between lateral and longitudinal growth indicates that the biological mechanisms of growth in the two directions are in some measure independent of each other.

In all three measures of development the growing lumbar or thoraco-lumbar area tends to be smaller in area and more

anteriorly placed in race X than in the other two races which is in harmony with the vertebral formulae and quantitative measurements previously noted by several investigators. This area in race IIIc, in comparison, is much more extensive. The striking localized differences between these races suggest the presence of growth differences which are specific in time and place and of genetic origin. It is logical, therefore, to examine populations at different intervals of time to determine the relative rate of change.

DISCUSSION

Such regional growth differences as have been described here in the rabbit are not new. The homoeotic variations of the adult have intrigued the morphologist since at least the time of Rosenberg (1876). Schultz ('38), for example, called attention to the relative differences in these same regions of the axial skeleton in different species, particularly between the lower and higher primates and man. He cited Aeby, who in 1879 dealt with age changes in relative length of cervical, thoracic, and lumbar regions. Nor is the observation new that these regions are manifest in embryonic development, since the variations in potentialities of localized growth areas are very little different from the fields and gradients which have so long interested the embryologist. At the same time, the quantitative approach to growth and size was one of the earliest methods to attract the geneticist, the physical anthropologist, and the practical animal husbandman. Limitations of the descriptive and statistical methods being applied have become increasingly apparent and have led to a search for new and more penetrating methods such as factor analysis and the study of populations of individuals in time, the so-called longitudinal approach. The criticisms of the older methods employed and tests of factor analysis have been ably presented in several papers, notably Robinow ('42) and Howells ('51 and '53). Robinow's analysis of the appearance of ossification centers seemed to yield three factors, a so-called "round bone," and "epiphysis" factor and a third of no

obvious meaning. It did not provide information as to the possible Mendelian nature, or the relation of these factors to endocrine influences, which Robinow apparently anticipated. Howell's ('51) analysis of head and face measurements, while appearing to isolate 7 factors, seems to have been equally disappointing insofar as finding the cause or causes is concerned. The difficulty appears one of relating the abstraction obtained to concrete biological processes.

The most significant fact gleaned from the present study is the observation that at this age the growth processes seem to be clearly definable both qualitatively and quantitatively (in place) and with a precision of definition in some degree approaching that of other genetic characters, a situation which has rarely been observed in mammalian growth, leastways internally. Furthermore, these innate differences in embryonic growth pattern of the axial skeleton seem only to redemonstrate and reemphasize facts which, although confirmed by several investigators, somehow have been overlooked in attempts to discover the specific effect of the gene in determining morphological variability and normal growth processes. In seeking an intelligent understanding of such processes it may be well to call attention to four well recognized characteristics of vertebral development.

The first of these is the generalized phenomenon by which initiation of new centers of ossification seems to occur where growth is temporarily retarded, whether it be induced by environmental influences such as temperature, by normal or abnormal influences inherent generally within the individual animal, or by those specifically localized (for bibliography, see Crary and Sawin, '55).

The second of these occurs in the pattern of development, which is quite different for centra than for neural arches. The neural arches in our previous study were shown to manifest the same general tendency (see legend fig. 1) to cranio-caudal order of appearance well recognized by anatomists and roentgenologists in man (Ruckensteiner, '31; Noback, '44; Noback and Robertson, '51). The centra tend

to be initiated in the lumbar region, and subsequent ossification is cephalad and caudad in a manner likewise comparable to man (see fig. 1). In both neural arches and centra the rabbit is peculiar in that these centers are first expressed in three groups, rather than in one (Crary and Sawin, '55). As development proceeds, identity of these groups disappears qualitatively, since sooner or later all centers must be present. In this quantitative study we find the same three groupings in the centra, although the boundaries between the second and third groups are tending to become obliterated by the relative growth of adjacent areas. That their identity remains through life, however, is evident by reference to Tanner and Sawin ('53) and further it is interesting to note how closely comparable they are (qualitatively) with the recognized and named groups of adult vertebrae. Thus, it appears that the characteristics which are associated with these groups of vertebrae can be, in a large degree at least, interpreted in terms of the growth processes involved in early development. In other words, the adult characteristics actually manifest landmarks of the growth processes which have preceded them. In these races they seem to do more, however, than provide a convenient vocabulary for use in discussion, because whenever changes in pattern occur, as shown in figures 1 and 2, they appear to involve these groups or combinations of groups as units rather than the individual vertebrae with only minor and specialized exceptions, such as the atlas or axis.

The fact that the centra pattern is not the same as that of the neural arches is of particular significance because it indicates an independence of origin, and of the genetic factors influencing these two parts of the vertebrae, which is not surprising in view of the relationships which have been noted between vertebrae, cord, and notochord by several investigators (see Holtzer, Holtzer and Avery, '55).

In our previous study based on incidence of ossification centers between races III and X, the differences observed could be interpreted on the basis of the non-overlapping differences in general body size and hence general growth

rate between the two races. However, in this study two facts suggest that general body size as described by Castle ('29) has only minor effects. They are first, that III and IIIc are of common origin and are not significantly different in body size, and second, that race IIIc is not only precocious but shows significant quantitative differences in a positive direction, whereas race X, which is also precocious compared with race III, shows negative quantitative differences in some regions and no differences in others. This indicates major influences of a localized nature when considered with respect to place alone. On the other hand, the obvious differences in embryonic patterns may be only an indication of localized differences at this particular time which could be balanced by other effects occurring later in embryonic or even postnatal development to give the same adult size as evaluated by weight. This emphasizes the importance of investigating these growth differences longitudinally in time and of hybridization studies which would either differentiate these influences genetically or supply a clue to their nature. Because of the genetically controlled animal stocks used here, this approach is now possible and is in progress.

The third characteristic of vertebral development, which is also well known with respect to the body generally, is that growth along the secondary axes (laterally and dorso-ventrally) is not always relatively the same as along the primary axis (Krogman, '43); that is to say, growth may be taking place laterally when it is not taking place longitudinally or dorso-ventrally. Growth in the two directions is not competitive, however. In several instances a high level of growth is progressing in both directions (laterally and longitudinally) simultaneously; for example, in IIIc (figs. 2C-D). It can also involve more than one adjacent group, for example, thoracic, thoraco-lumbar and lumbar groups in IIIc width (fig. 2D). This further emphasizes the independence of longitudinal and lateral growth and the likelihood that they are truly localized differences possibly induced by specific genes.

A further manifestation of this difference is apparent at the onset of ossification in certain individuals which manifest anomalous bipartite centra (fig. 1). Occasionally in other species these centra are bilateral and have given rise in at least one case to the conclusion that each centrum ossifies from two bilateral centers (Beadle, '31). Most workers, however, apparently never having observed these anomalies, are of the opinion that each centrum ossifies from one center. In figure 1 these bilateral centers occur in the thoracic region of embryos 140, 197, and 202. A second type of bipartite centrum is also apparent in vertebrae 19, 20, and 21 in individual 202. To our knowledge, the latter type (in tandem) has not been previously described in the literature. The full significance of these types is not at present clear, but their localized nature suggests an association with the existing growth processes, since they appear to be centered in those regions where critical growth changes are taking place. These are being studied more critically. In both races the bipartite ossification centers tend to occur in groups with bilateral centra anteriorly and in tandem groups posteriorly.

The fourth characteristic of development is the relationship between processes whose influences are brought to bear locally and those which act generally, such as those described by Castle ('29), Castle and Gregory ('29), and Gregory ('30). As described, the latter are polygenic and act in an equal and cumulative manner to affect adult body size and are expressed embryonically by the rate of the cell division. It has been shown elsewhere (Crory and Sawin, '56) that race IIIc, which is not larger in adult body weight than race III, is *at this* time actually growing more rapidly as judged by embryo weight, as well as by change in ossification patterns. Therefore, the differences between them could be due in part at least to influences acting in a general way upon the overall sequence of events in differentiation. However, the specifically localized differences in each of the three races described above and by Crory and Sawin ('57) are not entirely in harmony with the generalized influence and, in fact, seems to fit best

with an interpretation on the basis of interaction of both sources of influence, and in relation to time.

Involvement of more than one skeletal unit, or more specifically, a localized group of structures arising from regional growth influences, is a phenomenon which has been recognized a number of times. We have not only described it in connection with homoeotic variations of the vertebrae of rabbits but also with ventral spinous processes (Sawin, '46) and sternebrae (Peck and Sawin, '50). It has been discussed in connection with the vertebrae of primates (Schultz, '38), and in connection with certain single gene induced anomalies, notably the luxate (*lx*) (Carter, '53), and luxoid (*lu*) (Green, '55) genes in mice.

Carter has reported that *lx* causes a reduction in presacral vertebrae and that renal effects in greater or lesser degree also result. Green finds the number of presacral vertebrae increased in luxoid homozygotes, and the number of ribs in the heterozygotes, but that in crosses involving the two genes the double heterozygote is normal. Thus, the effects of the one abnormal gene may serve to balance the other. These differences are interpreted by Carter, Forsthoefel ('53), and Green as the result of displacements or shifts of the limb bud or inductor. This is a plausible mechanical explanation proposed as early as 1876 with regard to the pelvis by Rosenberg, but seems thus far to have been very difficult to verify. It seems to us in the light of the present study of growth processes in the vertebrae that these "shifts" may be more accurately explained perhaps on the basis of the inherent localized growth processes associated with these two genes, more specifically the relationship of growth rates in the longitudinal versus the transverse axis.

Earlier in this paper attention was directed to certain contributions to knowledge of growth processes made by morphologists, embryologists, geneticists, biometricians, anthropologists, and animal husbandrymen. Each of these groups of necessity has been led by the nature of the material or his particular background to approach the problem of

growth and development in different ways. Although individually the tremendous efforts expended seem to have been relatively ineffective in revealing the precise genetic background of normal growth and development, it would seem that the combination of the best thought and effort of all of these fields applied to controlled genetic stocks might be successful.

It appears that if these regions, fields, or gradients of growth can be further defined in this way in time by use of such stocks which lend themselves to hybridization and breeding in the successive generations customary in genetic analysis, a way is thereby opened for analysis (by something equivalent to the longitudinal approach of human growth studies), not only of the genetic background of a wide variety of morphological and functional manifestations, but also for many types of pathology and disfunction which may be associated with them.

SUMMARY AND CONCLUSIONS

Comparison has been made of the ossification patterns of the vertebrae of 21-day embryos of three races of rabbits. A total of 219 embryos were taken by Caesarian section. The races are closely bred and differ in the newborn and adult in general body size and in certain regional or localized growth areas previously described in the literature both qualitatively (by skeletal and vascular units) and quantitatively. The significant findings are as follows.

- (1) The regionally greater growth differences observed in these races postpartum, anteriorly in race X and more posteriorly in III and IIIc, are apparent in embryos at the time when ossification of the vertebrae is initiated. They are manifested by the incidence and size of ossification centers and by the overall magnitude or number of vertebrae involved.
- (2) Although the precocity in ossification of race X might be attributed solely to the difference in size, and therefore the rate of growth or cell division between races III and X, the differences between III and IIIc must be explained on

some other basis; possibly that of specific gene effects acting at different times in development, thus suggesting the importance of the longitudinal approach to problems of this kind. (3) The pattern of ossification of the rabbit, when initiated, resembles that of man in that neural arch centers tend to be initiated anteriorly and growth progresses in a cranio-caudal order, whereas centra centers are initiated in the mid-region of the axial column and their appearance and growth progress cephalad and caudad. It differs from man in that the ossification centers of both arches and centra tend to be initiated in at least three groups rather than one. The same general pattern of ossification occurs in all three races. It is upon these groups that localized growth influences seem to act in affecting racial differences in ossification patterns, rather than upon single morphological units. (4) Enlargement of ossification centers laterally along the secondary axis is not always the same as that along the primary; nor is it, in general, either competitive or compensatory, thus perhaps indicating further independent genetic control for growth in the two directions.

These localized growth processes are discussed with reference to homoeosis and as the basis of a possible new approach to the old problem of the specific effect of the gene in determining morphological variability and conformation, particularly if they can be studied longitudinally (in time).

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HAIR OF AUSTRALIAN ABORIGINES (ARNHEM LAND)¹

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The form of the hair of Australian aborigines has contributed to theories concerning the origin of these people. The hypothesis, supported by Hooton ('31), that the Australian is a mixture of an aboriginal frizzly-haired Melanesian and a primitive Caucasoid strain rests primarily on the hair form, a character referred to by Howells ('37) as "that stumbling block." Based on a study of data collected in 1927 by Warner from the native inhabitants of Northern Australia (Arnhem Land), Howells ('37) has proposed that, "the Australians are a major race which represents an earlier stage in the development of *Homo sapiens* than does any other existing race. . . . its characteristic wavy hair is probably older than the wooly hair of the Negro." In data collected during 1938-39 pertaining to the aboriginal populations of various and widely separated geographic areas Birdsell ('49) found evidence of three major racial elements on the mainland of Australia; the Oceanic Negritos represented by the Barrinean tribes in coastal north-eastern Queensland; the Archaic White or Caucasoid group concentrated in the Murray River drainage basin and the contiguous marginal coastal regions to the south and east; and a third group located around the shores of the Gulf of Carpentaria. This last group, he considers to be a fourth major racial group with a

¹ This investigation was supported (in part) by a grant-in-aid from the Wenner-Gren Foundation for Anthropological Research, Inc.

status equivalent to that of the Negroid, Mongoloid and Caucasoid. Their hair form, he describes as wavy to straight. The anthropological significance of Australian aborigines, together with the importance of hair form and color as racial characteristics, justify a detailed examination of the morphology of their hair.

During the Arnhem Land Expedition in 1948 one of us (F.M.S.) collected samples of hair from 191 individuals. Observations of form, color, index, cross sectional area, medullation and scale count will be presented and the findings compared with those of other racial groups.

MATERIAL AND METHOD

The geographical areas involved are the large island called Groote Eylandt, Yirrkala on the mainland, and Milingimbi, one of the Crocodile Islands. Groote Eylandt lies off the coast in the Gulf of Carpentaria in relation to the two areas indicated by Howells ('37) as Northeast Arnhem Land and Roper River, whereas both Yirrkala and Milingimbi are included in Howells's Northeast Arnhem Land. All three areas are included in the division which Birdsell ('49) considers to be inhabited by Carpentarians, the third and last major racial element to enter Australia. The subjects are distributed according to locality and sex as follows:

	GROOTE EYLANDT	YIRRKALA	MILINGIMBI	TOTAL
Male	36	44	7	87
Female	39	55	10	104
Total	75	99	17	191

The ages range from 1 to 70 years. Each series includes a large number of related subjects.

The hair samples were cut close to the vertex. Those examined came from 117 individuals, 50 each of the larger groups (25 of each sex) and all of the Milingimbi. The method utilized in evaluating the various characteristics have been applied to hair of other peoples. Each method will be described under the characteristic to which it pertains.

OBSERVATIONS

Form. The gross form of the hair has been determined according to Martin's classification ('28). Only 4 of Martin's hair forms are supplied in this study: straight, broad wave, deep wave and curly. No attempt was made to distinguish between the forms designated *straff*, *schlicht*, and *flachwellig* (the lissotrich or straight-hair group); hair of any of these three forms was classified as straight. The broad wave, deep wave and curly forms (*weitwellig*, *engwellig* and *lockig*) constitute the kymatotrich or wavy-hair group. And, of the ulotrich or kinky hair series, which is comprised of 5 forms (*gekraüsel* to *spiralig* inclusive), none was present.

The most frequently occurring hair form for both sexes of all three groups is the broad wave with the remaining samples divided rather equally among the straight, deep wave and curly forms. The distribution in per cent is as follows:

	GROOTE EYLANDT		YIRRKALA		MILINGIMBI	
	Male	Female	Male	Female	Male	Female
Straight	24	16	8	24	14	0
Broad wave	48	56	48	40	43	60
Deep wave	16	24	24	8	29	30
Curly	12	4	20	28	14	10

Color. For designating color each sample has been assigned the letter of the matching color on the Haarfarbentafel of Fischer and Saller ('28). All are within the color range of brownblack (U to Y inclusive) and with more cases occurring at the darker end of the range than at the lighter. In the samples from three individuals (aged 55-60) there is a large proportion of gray hairs but in no sample are all the hairs gray. The color distribution in per cent is as follows:

	GROOTE EYLANDT		YIRRKALA		MILINGIMBI	
	Male	Female	Male	Female	Male	Female
U	20	4	0	0	0	0
V	16	16	0	0	14	0
W	16	16	12	0	43	30
X	48	44	64	20	0	60
Y	0	20	24	80	43	10

Index and area. Since the index or shape of the cross section of the shaft and the area or size of the cross section has been determined from the same hairs the two characters are considered together. Approximately 25 hairs from each sample were sectioned transversely with the J. I. Hardy thin cross-section device (Trotter and Duggins, '48). The index was determined by use of the formula:

$$\frac{\text{least diameter} \times 100}{\text{greatest diameter}};$$

and the area in mm^2 by the formula:

$$\frac{1}{2} \text{ greatest diameter} \times \frac{1}{2} \text{ least diameter} \times 3.1416$$

The average index and area of hairs from each sex of each group are:

	GROOTE EYLANDT		YIRRKALA		MILINGIMBI	
	Index	Area (mm^2)	Index	Area (mm^2)	Index	Area (mm^2)
Male	72.6	.0037	67.1	.0044	67.4	.0033
Female	70.0	.0033	67.8	.0037	65.3	.0032

Differences between the average indices and between the average cross-sectional areas of the three groups are small. The indices of the hair of the Groote Eylandt subjects are somewhat higher than for either of the other two groups, whereas the area is smallest for the Milingimbi and largest for the Yirrkala. Within each group the area is slightly greater for the males than for the females; in the case of index the males also exceed the females except for the Yirrkala whose average index for the females is very slightly higher than that for the males.

Medullation. Approximately 25 hairs from each sample were placed parallel on a slide and the length of each shaft scanned through the low power of the microscope for evidence of a medulla (Duggins and Trotter, '50). Classification followed that of Wynkoop ('29): absent, scanty, broken and continuous. The continuous medulla was found least often and the scanty most often. The percentage of hairs showing

a medulla of any type was determined for each individual. Since it is known that medullation is in a state of flux in the very early years of life (Duggins and Trotter, '50) those subjects under 5 years of age have been excluded in the determination of the average percentage of hairs with medullas. The incidence (in per cent) of hairs with medullas for each group (including those 5 years of age and older) according to sex are as follows:

	GROOTE EYLANDT	YIRRKALA	MILINGIMBI
Male	34.4	63.0	60.8
Female	35.8	50.5	69.2

The Groote Eylandt subjects have hair with the lowest incidence of medullation and the Milingimbi with the highest. An examination of the incidence of each type of medulla shows that the continuous type occurs in essentially the same number of hairs in each group (range 3–7%); that the discontinuous type, although slightly higher in incidence, occurs in approximately the same percentage in each group (range 9–16%); but that the fragmentary type is seen in many more hairs in the Yirrkala and Milingimbi (41% and 51%, respectively) than in the Groote Eylandt (18%). Thus, it is the fragmentary type of medulla which accounts chiefly for the difference in incidence of medullation among the three groups.

Scale count. A scale count indicates the number of scales in the cuticle whose free edges cross a longitudinal straight line of given length. For each sample counts were made at approximately 25 different sites (Trotter and Duggins, '50), over a distance of 0.16 mm of the shaft. The number of hairs from each sample utilized for these counts averaged 4. The average number of scales (and the range) per unit distance for each group is as follows:

	GROOTE EYLANDT	YIRRKALA	MILINGIMBI
Male	19.3 (17–24)	19.8 (18–23)	19.0 (17–21)
Female	19.8 (18–23)	19.7 (18–22)	19.3 (18–21)

TABLE 1

Data from hair samples of Groote Eylandt subjects according to age

SUBJECT	AGE	FORM	COLOR	INDEX	AREA	MEDULLA INCIDENCE	SCALE COUNT
	<i>years</i>				<i>mm²</i>	<i>%</i>	<i>per 0.16 mm</i>
Males							
86	1	S	W	87.6	.000966	33	22.1
37	3	D	U	72.9	.002808	12	17.1
28	4	B	V	82.2	.002805	36	18.8
65	5	B	W	64.2	.003022	8	20.2
77	5	S	W	80.8	.002135	20	17.0
80	5	S	V	80.9	.002313	22	18.5
36	6	B	U	71.1	.002386	60	16.6
27	7	B	V	80.4	.002932	32	18.7
41	8	S	U	63.7	.002518	24	17.6
44	8	B	U	77.3	.002774	80	20.0
79	9	S	X	80.4	.003251	60	20.7
78	11	S	U	76.8	.003840	95	18.4
63	12	B	X	65.8	.004137	24	19.6
62	17	D	X	72.5	.004317	28	18.0
88	24	C	V	70.3	.005126	64	19.9
82	27	C	X	61.1	.005221	20	20.7
53	28	B	X	71.4	.003486	0	20.5
21	40	C	X	81.8	.004133	21	19.7
71	42	B	X	63.7	.004119	56	17.1
29	45	B	X	71.1	.003607	25	19.2
89	52	D	X	63.9	.003742	44	23.5
97	52	B	W	72.8	.003476	23	18.9
23	54	D	X	62.9	.004669	12	19.3
47	55	B	X	67.9	.002655	14	19.3
57	60	B	X	70.8	.003819	23	21.2
Females							
83	3	B	W	82.2	.002206	32	18.0
81	3	S	V	79.9	.001957	20	20.1
43	4	D	U	72.1	.002575	28	18.8
35	7	B	W	81.7	.002384	12	19.0
42	7	B	V	84.8	.002766	15	20.0
93	9	B	X	68.4	.002862	68	21.2
26	11	S	V	68.1	.003216	80	19.0
39	12	D	Y	70.0	.003984	0	20.5
91	14	S	V	83.4	.003387	8	22.9
75	15	D	X	72.3	.005000	50	21.0
25	17	B	Y	69.8	.004690	30	19.9
74	18	B	Y	70.0	.003109	12	19.4
99	20	B	X	74.0	.003443	65	19.8
66	21	D	Y	68.9	.004173	24	18.6
61	28	B	X	59.6	.003743	56	19.6
32	30	B	X	63.9	.002219	56	18.5
31	32	B	W	63.6	.003174	52	18.2
48	32	D	X	63.2	.003885	50	21.1
73	32	C	X	64.6	.003802	40	20.0
30	35	B	Y	63.8	.003577	52	18.4
24	38	B	W	64.6	.003480	41	21.4
58	45	B	X	57.7	.003487	20	17.6
72	50	B	X	69.8	.002675	8	21.3
98	50	D	X	64.5	.003593	28	19.5
46	60	S	X	70.2	.001941	20	20.4

TABLE 2

Data from hair samples of Yirrkala subjects according to age

SUBJECT	AGE	FORM	COLOR	INDEX	AREA	MEDULLA INCIDENCE	SCALE COUNT
	<i>years</i>				<i>mm²</i>	<i>%</i>	<i>per 0.16 mm</i>
Males							
209	8	S	X	82.3	.002808	44	19.7
210	9	S	X	73.2	.003643	56	20.1
176	10	B	X	77.2	.003416	68	19.4
143	14	B	X	63.4	.005606	92	20.0
223	16	B	Y	66.4	.005799	72	19.1
174	17	D	X	66.4	.003085	28	22.8
161	18	C	Y	64.9	.005116	80	21.5
132	19	B	W	66.4	.003794	64	18.3
137	19	B	X	77.7	.005532	44	19.1
130	20	B	X	69.3	.003657	24	19.2
131	23	D	Y	63.8	.005594	36	21.2
135	24	D	W	64.9	.003526	76	18.8
160	25	C	Y	67.6	.006564	52	21.0
144	27	B	Y	71.7	.002980	96	19.9
171	27	B	W	75.8	.004119	32	19.6
229	33	C	X	67.2	.004828	64	19.4
162	35	C	X	60.6	.006257	68	21.1
163	37	B	X	66.7	.004226	68	19.2
164	37	D	X	68.8	.003788	72	20.6
141	37	B	X	69.6	.003832	48	15.8
140	37	D	Y	52.7	.003316	92	19.7
205	45	B	X	65.3	.003555	64	19.2
127	47	D	X	65.4	.004144	40	18.8
166	47	C	X	54.5	.005626	100	19.7
134	60	C	X	56.9	.004486	96	20.8
Females							
123	8	S	Y	72.0	.004110	64	18.8
220	9	S	X	75.8	.002889	39	21.3
227	10	S	Y	72.5	.003281	48	18.1
107	11	B	Y	72.1	.003543	84	20.4
124	11	S	X	60.2	.003389	42	21.1
148	11	S	Y	63.4	.003184	28	21.3
215	12	B	Y	73.7	.002738	28	19.2
228	12	B	Y	67.2	.003239	36	18.6
115	16	C	Y	63.1	.005654	41	21.2
121	16	D	Y	66.9	.004983	52	21.5
105	18	B	X	74.0	.002612	12	20.9
213	20	B	Y	67.7	.005153	80	19.4
217	21	B	Y	65.0	.003563	48	19.9
120	22	C	Y	60.9	.005405	64	20.5
118	27	C	Y	69.7	.004297	52	20.4
119	27	C	Y	69.8	.003734	56	18.1
207	33	B	Y	56.7	.003010	36	19.4
113	35	C	X	63.0	.003371	10	21.0
111	37	C	Y	67.6	.003451	76	19.5
122	37	B	Y	63.9	.003973	70	20.2
117	40	S	X	80.8	.002887	36	20.1
224	43	D	Y	62.1	.004107	92	20.2
218	47	B	Y	58.6	.002889	56	21.2
216	63	C	Y	82.6	.002771	40	19.7
226	63	B	Y	65.9	.003024	72	20.5

The number of scales per unit distance is remarkably uniform for all three groups as well as between the sexes of each group.

Observations and measurements of the hair of each subject are recorded in tables 1, 2, and 3.

TABLE 3

Data from hair samples of Milingimbi subjects according to age

SUBJECT	AGE	FORM	COLOR	INDEX	AREA	MEDULLA INCIDENCE	SCALE COUNT
	<i>years</i>				<i>mm²</i>	<i>%</i>	<i>per 0.16 mm</i>
Males							
189	5	S	V	75.8	.002717	60	19.1
202	5	B	W	66.1	.002966	56	20.5
199	12	B	W	74.8	.002381	44	21.0
188	15	B	Y	62.4	.003191	92	17.6
185	21	D	Y	62.4	.004357	72	18.0
200	30	C	W	62.5	.003962	44	20.6
186	57	D	Y	70.2	.003803	56	16.5
Females							
195	5	B	W	71.4	.003279	64	21.2
198	8	D	X	72.5	.003303	64	19.7
194	9	B	W	62.0	.002413	56	20.2
192	11	B	X	54.6	.002919	84	18.9
191	17	D	X	65.0	.004718	100	18.0
197	22	B	Y	65.8	.003004	36	18.0
190	23	C	X	62.9	.003303	76	19.0
201	27	D	W	66.5	.003349	72	20.8
196	33	B	X	65.9	.002663	40	17.9
193	35	B	X	66.1	.003251	100	18.8

DISCUSSION

The Australian aborigines from the localities of Groote Eylandt, Yirrkala and Milingimbi have hair which is similar in form, color and scale count, compares closely in index and area, but is quite different in incidence of medullation.

Hair samples representing the three major races were selected for comparison with the hair of Australian aborigines. The Caucasoid samples were taken from a collection made in Saint Louis in 1928; the Mongoloid samples were obtained

from Chinese students attending the University of Wisconsin in 1922; and the Negroid hair samples were collected in Northern Zululand, South Africa in 1913-14 by V. Sük. Certain observations on the American White series have been reported in 1930 by the senior author. The data for the Chinese and South African series are taken from a study in progress (Trotter and Duggins).

The most frequently occurring form and color and the average index, area, incidence of medullation and scale count may be summarized for the three groups of Australian aborigines and for the representatives of the three major races as follows:

	GROOTE EYLANDT	YIRREKALA	MILINGIMBI	CAUCASOID	MONGOLOID	NEGROID
Form	wavy	wavy	wavy	wavy	straight	kinky
Color	brown- black	brown- black	brown- black	brown	brown- black	brown- black
Index	71	67	66	74	80	55
Area (mm ²)	.0036	.0041	.0032	.0033	.0060	.0031
Medulla incidence (%)	35	57	66	36	73	26
Scale count (per 0.16 mm)	20	20	19	21	21	20

It may be noted that the characteristics of Caucasoid hair (except color) fall in the range between Mongoloid and Negroid. The form of the hair of Australian aborigines is wavy like that of Caucasoids but the color is brownblack like that of Mongoloids and Negroids. The index lies between that of the Mongoloid and Negroid as does also the index of the Caucasoid; however, the index of the Australian aborigines is somewhat lower than the index of the Caucasoid suggesting that the wavy form extends from Caucasoid toward Negroid rather than toward Mongoloid. The area or size of the hair approximates the Caucasoid but extends toward the Mongoloid rather than the Negroid. The incidence of medullation is higher than in the Negroid series and lower than in the

Mongoloid series; the Groote Eylandt subjects are like the Caucasoids in this character while the Yirrkala and Milin-gimbi show a considerably higher incidence of medullation. The scale count differs so slightly among the three major races and also among the three groups of Australian aborigines that the differences cannot be considered to be significant; the indication is, however, that the Australian aborigines are like Negroids with some tendency toward an even lower scale count.

The evidence suggests that hair of Australian aborigines is more nearly like the hair of Caucasoids (except in color) than of either Mongoloids or Negroids; that the size or area of cross section and incidence of medullation extend toward the Mongoloid type; and that index or shape or cross section extends toward the Negroid type. The dermatoglyphics (palm and finger prints) of the Australian aborigines (Groote Eylandt and Yirrkala) have been studied by Cummins and Setzler ('51). The index of pattern intensity (a measure of complexity) established a new high among known populations. Unlike the dermatoglyphics of the Australian aborigines the characteristics of their hair fall within the range of the three major races.

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EXTERNAL CRANIAL VOLUME AS AN ESTIMATE OF CRANIAL CAPACITY

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THREE FIGURES

Cranial capacity, related as it is to the volume of the brain, is a measure of both anthropological and clinical interest, but it can of course only be estimated indirectly in living subjects. Several attempts have been made to compute the cranial capacity by means of formulas incorporating the length, breadth, and height of the skull. But as Bröste and his collaborators have shown ('57), such procedures are of small use, as there can be found no clear correlation between the calculated values and the directly measured internal volumes. For clinical purposes, pediatricians have employed the circumference of the head as a measure of cranial capacity, but a priori we must expect this to be even less accurate than the formulas that take account of all three dimensions. In skeleton examinations, defects in the base of the skull may make the direct (millet seed) method impracticable.

In the present investigation it has been our purpose to make a direct determination of the external volume of the skull, and to decide whether this measure is of practical value in the estimate of cranial capacity.

The volumetric determination comprises only the part of the skull which is above a plane throughinion and glabella. There are three main reasons for this: (1) with due correction for the thickness of the integuments and the volume of the hair the method might be used on living subjects; (2) the said plane corresponds approximately to the base of the brain; (3) it might become possible to determine the capacity of skulls with large basal defects.

Figure 1 illustrates the method: a container is filled with water to the brim; the skull is immersed until the surface reaches the horizontal glabella-inion plane, and the displaced water is collected in a measuring-glass. In order to eliminate the error caused by absorption of water through the walls of the skulls, the latter were weighed before and after the immersion, and the weight difference was added to the volume

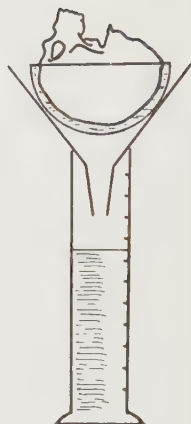


Fig. 1 Technique for measuring the external cranial volume.

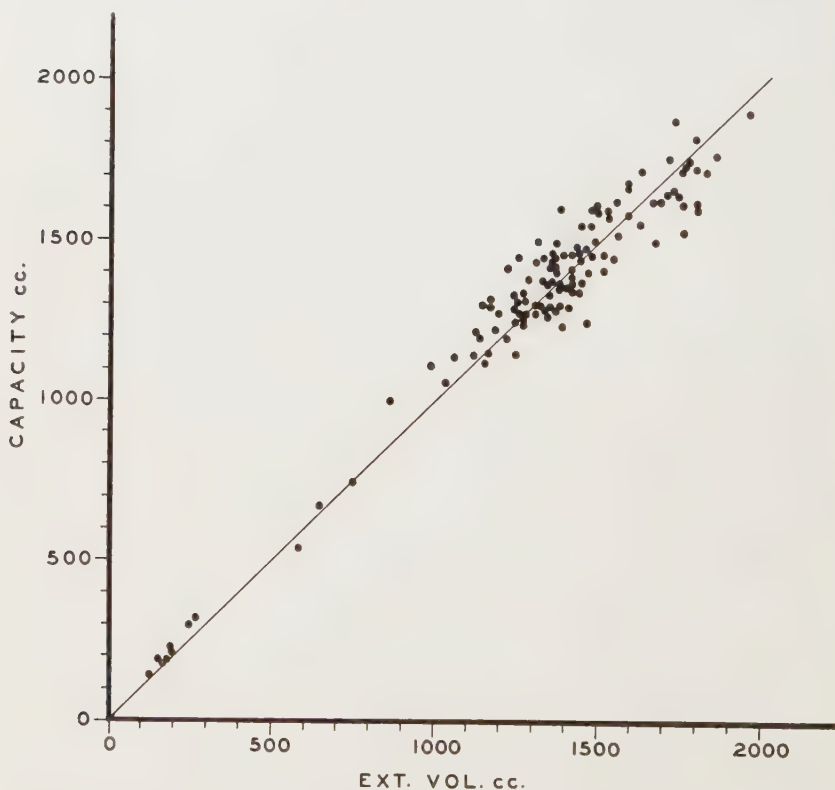


Fig. 2 Relation between external and internal cranial volumes in a series of 121 skulls.

measured in the glass. Repeated measurements showed that the error amounted to less than $\pm 5\%$.

One hundred and twenty-one skulls of all sizes were examined, and their external volumes compared with their capacities as determined by the millet seed method. Figure 2 shows that there is a distinct correlation between external and internal volumes: the points are distributed evenly around a straight line starting from zero with an inclination of 45° , so that the relationship can be expressed as 1:1. (It would thus seem that the posterior cranial fossa, which is above the water level, is equivalent in volume with the immersed bony wall.) Contrary to this, the relationship: circumference/

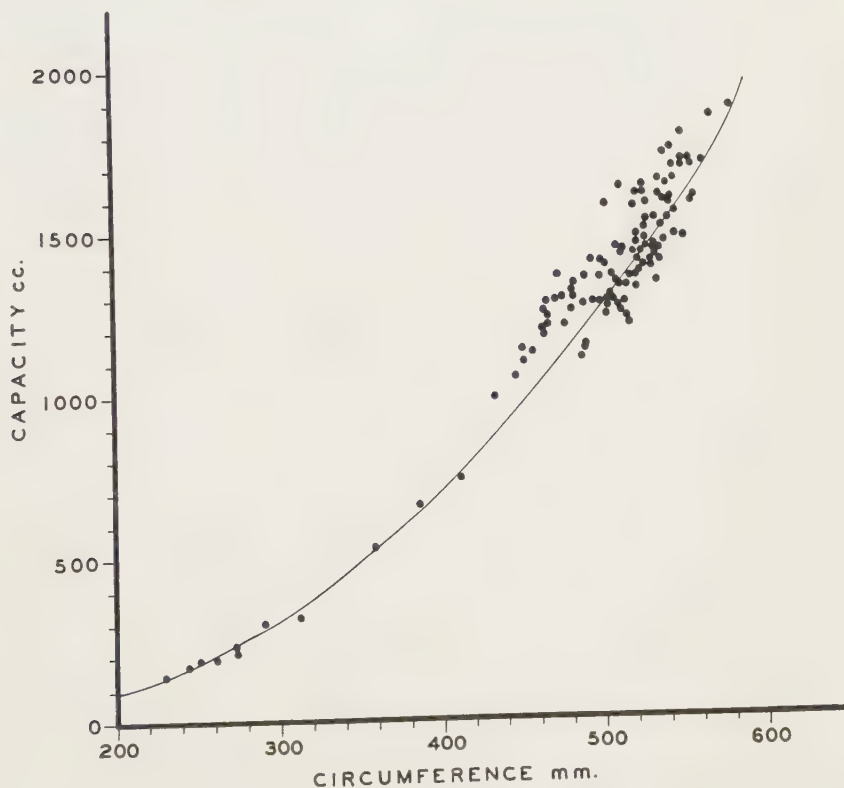


Fig. 3 Relation between cranial circumference and internal volume in a series of 121 skulls.

capacity (fig. 3) cannot be expressed so simply, as the points are situated along a curved line. If, in both figures, we omit the lowest eleven values and base a regression analysis on the remaining, more frequently occurring data, we get the following equation for figure 2:

$$y = 0.8 x + 280$$

(standard deviation: 80 cc)

and for figure 3:

$$y = 5.43 x - 1346$$

(standard deviation: 100 cc)

These calculations show that the external volume gives a more accurate estimate of cranial capacity, i.e. an estimate with a smaller standard deviation, than does the circumference. For practical purposes, the formula: external volume = capacity will do better than the equation, in spite of the fact that it raises the standard deviation from 80 to 87 cc. This disadvantage is outweighed by the great simplicity of the formula. It remains to be seen whether the volumetric method described in this paper can be put to use in clinical and post mortem studies.

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REVIEWS

EVOLUTION, GENETICS, AND MAN. By Theodosius Dobzhansky, 1955. John Wiley and Sons, New York, IX, 398 pp., \$5.50.

Introductory Physical Anthropology, or as it is more appropriately named, an Introduction to Human Evolution, is ready for drastic change. This ubiquitous course has a Cinderella-like quality; it is full of virtues, but badly treated. In some colleges it is the only course in Anthropology. In others, it is the first to which the major is exposed. It captures the interest of the casual student and provides him with life-long perspectives. It recruits enough majors to be of vital concern to every department. Where it serves as a natural science requirement, it carries a work-horse load of student enrollment and in the dean's eyes justifies a top-heavy expansion of anthropological faculty in cultural subfields at advanced levels. Despite its specialized approach to man, it is taught by archaeologists, sociologists, ethnologists, natural scientists from every field, and even majors in English.¹ Of the hundreds of such courses taught in this country, perhaps a dozen are in the hands of competent specialists. In catalogue phrasing, the epitaph of this course may one day read "Taught by the staff."

This unhappy state of affairs results from two factors: first, the widely held belief that introductory courses should be taught by those who know the least about the subject; second, the lack of any anthropological text for the course which recognizes the last two decades of progress in the biological interpretation of the processes of evolution. Such a modern text is not going to be written by a cultural anthropologist, and it is doubtful whether physical anthropologists of this generation are likely to produce one with sufficient biological authority. Perhaps the basic text for such a course must be written by a biologist. Four books have been written for introductory courses in organic evolution. Romer's *Man and the Vertebrates*, first published in 1933, emphasizes the descriptive sequences of evolution, and is further marred by retaining Griffith Taylor's curious ideas concerning the evolution of modern human races. Colbert's *Evolution of the Vertebrates* ('55) serves well as an introduction to vertebrate paleontology but is unsuitable for our purpose because of its limited scope, lush terminology, and high price. Moody's

¹ Name provided upon request.

Introduction to Evolution ('53) is much more acceptable since it is comprehensive and clearly written. It is lacking only in that its appliqué treatment of genetics, which is presented only after the evolutionary pattern has unfolded, puts this organizing field after the event. For those anthropologists who wish to modernize slowly, this is a useful text.

The fourth text has been written by Professor Dobzhansky as a guide to courses devoted to the study of biological evolution. He only suggests *Evolution, Genetics, and Man* as collateral reading for courses in human evolution. He has written more broadly than he knew, for his book serves admirably as the main text to introduce human evolution, provided that the lecturer will furnish further anthropological data. Since it is far easier to reach the student on the latter descriptive level than it is to effectively teach the basic biology of evolution, the choice is not a hard one to make.

The key in which Dobzhansky has written is best given in his own words.

Biological evolution is a part of the evolution of the cosmos. The rise and development of mankind are a part of the story of biological evolution. Man cannot reach a valid understanding of his own nature without a knowledge of his own biological background. It may then be that the study of evolutionary biology is the most important, practical endeavor open to the human mind. Accordingly an effort is being made in this book to show the student that biology is not only a craft which is interesting to technicians and devotees but also a part of the fabric of modern humanistic thought. I am conscious that the goal is too ambitious and that it has not been fully attained.

Dobzhansky's text is more modern in its approach than Moody's, and it derives this advantage from its full initial integration of genetics with the theory of evolution. Lest the idea of incorporating genetics into evolutionary theory frighten some teachers, it is worth mentioning that of the fourteen chapters in the book but three in their entirety and parts of a few others are devoted to the subject. Instructors will be wise to remember that modern evolutionary theory cannot be taught without genetics as the organizing principle.

A scanning of chapter contents will do much to reveal the flavor of Dobzhansky's treatment. The book opens with the "Nature and Origin of Life" which ably sets the perspective for the total work. There follow three chapters which form the genetical background: "The Gene as the Basis of Evolution"; "Chromosomes as Gene Carriers"; and "Heredity, Environment, and Mutation." With the

foundation poured, the student is then brought to grips with the structuring of evolution in "Elementary Evolutionary Changes or Microevolution," "Natural Selection and Adaptation," "Individuals, Populations, and Races," and "Species." Chapter 9 on "Evolution Under Domestication and Evolution by Polyploidy" brings the anthropological student new perspectives to materials with which he may be more familiar. "Evolution of the Organic Form and Function" continues the main stream of thought with the author's very effective blending of definitions, example, and theory. Chapter 11 is of less urgency to anthropologists, and may be left as optional reading. Its values will not go unappreciated since it concerns "The Evolution of Sex."

In his twelfth chapter, "Historical Record of Organic Evolution," the author selectively samples the unfolding story and manages in thirty-odd pages not only to sketch the major outlines, but to use it to illustrate an important segment of evolutionary theory. This chapter is so compressed in its writing that the reviewer supplements class reading with the first volume of the Pelican edition of Romer's *Man and the Vertebrates*.

"Human Evolution," the next chapter, sweeps through the primates and fossil man, and living races in less than forty pages, and to traditionally-minded anthropologists, this may weigh against adaptation of this text. It is, however, about a proper weighting for the subject in a general text for organic evolution, and it should be remembered that the instructor's lectures in the anthropological course and outside readings can insert sufficient descriptive data into the student mind.

In a final section, Dobzhansky deals with "Chance, Guidance, and Freedom in Evolution," giving a philosophical survey of such subjects as finalism, orthogenesis, orthoselection, allometric growth, progress in evolution, preadaptation, and evolutionary ethics, among other topics.

This excellent book is written so compactly that a single short paragraph may require several readings for comprehension. It will require the average student to reach for its meanings. In an age when pedagogical pap is too prevalent, many students will sense that it is a privilege to be exposed at a mature level to one of the most exciting areas of human knowledge through the writings of one who has contributed much to our over-all comprehension of evolutionary processes.

Since a reviewer is suspect if in his enthusiasm he does not record any of the author's inevitable errors, a few have been found and are noted. The Old Stone Age in Europe (p. 4) is given as ranging from 20,000 to 50,000 years ago. This dating probably should refer to the

Middle Paleolithic. The text (p. 54) does not agree with figure 3.8 which illustrates an experiment with a *Drosophila melanogaster* to show genetic linkage. The author, unfortunately, falls into a pattern — almost universal with anthropologists — with regard to illustrating the type of the Australian aborigine. He has rejected the published illustrations of the Murrayian and substituted under that title an overworked old Aranda man who first appeared in Spencer and Gillan's *The Arunta* ('27, p. 28). This distinguished-looking old native is about six sigma out on the primitive side of the population and gives a quite erroneous impression of Australian morphology. Such minor errors do not significantly mar the utility of the text.

The reviewer has more than the usual reasons for applauding *Evolution, Genetics, and Man*, for he has used it as the primary text for two semesters in a largely attended course in introductory human evolution. It serves to restore a proper balance to such an offering by providing the basic biological theory of organic evolution in the text, where it belongs, and by freeing the lecturer to discuss supplementary materials and descriptive data as they apply to man. One may predict that Dobzhansky's book will be adopted rather slowly, since to teach from it requires more than a casual acquaintanceship with the descriptive data which anthropologists like to think is exclusively their property. It promises, however, to upgrade evolutionary theory in the whole of anthropology; and in time it may even force reluctant departments to hire physical anthropologists to teach the subject.

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PRIMATES (COMPARATIVE ANATOMY AND TAXONOMY).

- I. Strepsirhini. By W. C. Osman Hill, pp. xxiv + 798. 5 pounds 5 shillings. University Press, Edinburgh. 1953; II. Haplorhini: Tarsioidea. By W. C. Osman Hill, pp. xx + 347. 63 shillings. University Press, Edinburgh. 1955.

The need for an up-to-date comprehensive reference work dealing with the biology of the order Primates has long been recognized. With this in mind, Osman Hill has set himself the task of covering the anatomy, development, psychobiology, and taxonomy of the entire order in a series of volumes, including both living and fossil forms. The series was inaugurated in 1953 by a volume devoted to the lemurs. This was followed, two years later, by a second volume dealing with

the tarsiers. According to the author's plan, a number of additional volumes on the various simian primates will eventually appear.

Hill has set himself a truly Herculean task. Let me say at once that his effort is highly praiseworthy; for, in my opinion, he is doing it about as well as any one person could. But the deficiencies of commission and omission of these first two volumes poignantly demonstrate the impossibility for any single individual to treat the biology of the Primates in a truly adequate manner — this despite the admittedly tremendous gaps in our knowledge of these animals. For, even with these still existing gaps, knowledge of primates has grown with leaps and bounds during the past century. That the author has produced two such useful volumes is therefore all the more remarkable.

Following Pocock ('18), Hill divides the order Primates into two groups, or grades, the Strepsirhini and the Haplorhini. The former is composed of the lemurs, both lorisiform and lemuriform; the latter comprises all other primates, hence the tarsiers, both groups of monkeys, the anthropoid apes, and man. In my opinion, this taxonomy is unfortunate; for the division into Strepsirhini and Haplorhini is based upon a single character of doubtful fundamental significance. It must be realized, however, that classification of the tarsiers is not a simple matter, viewed either horizontally or vertically, as will be discussed in greater detail below.

The tupaoids or tree-shrews are patently even more of a taxonomic problem than the tarsiers. Ever since Kaudern ('10) and Carlsson ('22) drew attention to their possession of morphological resemblances to the lemurs, they have been shuttled back and forth between the Insectivora and the Primates. The problem is much like that involving *Seymouria*, that Lower Permian fossil which can be regarded as either the most advanced amphibian or the most primitive reptile. Depending upon one's point-of-view—or even upon one's mood—the tree-shrews can be regarded as actual insectivores, or as constituting a separate order of their own that is intermediate to the Insectivora and the Primates, or as a distinct group of primates, or, more dubiously, as primitive lemuriforms. Hill has chosen to exclude them from the order Primates, an action that is certainly quite as justifiable as their inclusion. I believe, however, that their uncertain taxonomic position makes it imperative that the tupaoids be considered in any thoroughgoing discussion of the order Primates, regardless of whether one classes them as actual Primates or not. For this very taxonomic purgatory of the tree-shrews clearly demonstrates the lack of sharp distinction between insectivores and primates and emphasizes the essentially generalized character of the Primate order. Hence it seems unfortunate—even though it be defensible—that the author has

seen fit completely to ignore the tree-shrews in his volume on the Strepsirhini.

To consider Volume I first: Hill's Strepsirhini has two suborders, Lorisioidea and Lemuroidea. The Lorisioidea are divided into the families Lorisidae and Galagidae. The Lorisidae have 5 genera (*Loris*, *Nycticebus*, †*Indraloris*, *Arctocebus*, *Perodicticus*), the Galagidae 4 genera (*Galago*, *Euoticus*, *Galagoides*, †*Progalago*).

The Lemuroidea comprise 8 families, of which 5 are wholly extinct. Family Lemuridae has 2 subfamilies, Cheirogaleinae (genera *Microcebus*, *Cheirogaleus*, *Phaner*) and Lemurinae (genera *Hapalemur*, †*Prohapalemur*, *Lemur*, *Lepilemur*). Family †Adapidae is divided into 2 subfamilies, †Adapinae (genera †*Pronycticebus*, †*Adapis*, †*Anchomomys*, †*Caenopithecus*, †*Protoadapis*, †*Europolemur*, †*Amphilemur*) and †Notharctinae (genera †*Notharctus*, †*Pelycodus*, †*Aphanolemur*). The subfamilies Indriinae (genera *Propithecus*, †*Neopropithecus*, †*Mesopropithecus*, *Avahi*, *Indri*, †*Archaeoindris*, †*Palaeopropithecus*) and †Archaeolemurinae (genera †*Archaeolemur*, †*Hadropithecus*) constitute the family Indridae. The remaining families are the †Megaladapidae (genera †*Megaladapis*, †*Megalindris*, †*Lemuridothorium*), Daubentoniidae (genus *Daubentonia*), †Plesiadapidae (genera †*Pronothodectes*, †*Plesiadapis*, †*Chiromyoides*, †*Platychoerops*, †*Megachiromyoides*, †*Phenacolemur*, †*Trogolemur*, †*Uintasorex*), †Apatemyidae (genera †*Jepsenella*, †*Labidolemur*, †*Teilhardella*, †*Eochiromys*, †*Apatemys*, †*Heterohyus*, †*Stehinella*, †*Sinclairiella*), and †Carpolestidae (genera †*Elphidotarsius*, †*Carpodactes*, †*Carpolestes*). It may be noted that the taxonomic positions of the last three families, and especially those of the †Apatemyidae and the †Carpolestidae, are far from being settled. Indeed, it is just possible that the two latter families actually may not be primates at all.

The anatomical descriptions are well done, but, unfortunately, there is too much repetition. Thus, many of the same anatomical details are repeated under several or even more headings. To use the true lemurs as an example, their morphology is described successively under Strepsirhini collectively, suborder Lemuroidea, subfamily Lemurinae, genus *Lemur*, and, finally, the several species of the genus. The same applies to the galagos and, in lesser degree, to other genera.

The list of literature relating to Strepsirhini, while extensive—it comprises 686 references—is regrettably incomplete. Not only are a number of important contributions not included, but there is no reference dated later than 1948 (5 years prior to the publication of this volume). Only 16 (2.3%) of the references appeared after 1943,

and merely 24 (3.5%) after 1940. It seems unlikely that this paucity of recent publications can be attributed entirely to World War II, particularly when comparison is made with the bibliography pertaining to the tarsiers (see below).

Without any desire to denigrate Volume I, which, after all is said, is a first-rate contribution to zoology, paleontology, and anthropology, Volume II impresses this reviewer as a more felicitous effort. This can probably be attributed to several factors, namely, that the tarsiers are a smaller, more compact group than the lemurs, that Hill has had a more recent intimate contact with the tarsiers, and that the author has obviously profited greatly from his experience with the first volume.

Nearly one-third of Volume II (103 pages) is devoted to a very useful survey, by systems, of the anatomy, embryology, reproductive physiology, and psychobiology of the Haplorhini collectively. This is followed by a similar, detailed treatment of the tarsiers, both living and fossil.

Hill's Haplorhini has two suborders, Tarsiioidea and Pithecoidea, the latter embracing all of the monkeys, apes, and man. The Tarsiioidea are composed of 2 families, one of which is entirely extinct. Family Tarsiidae includes only a single, Recent genus, *Tarsius*. Family †Microchoeridae is formed of 5 subfamilies, namely, †Paromomyinae (genera †*Palenochtha*, †*Palaechthon*, †*Paromomys*, †*Plesiolestes*), †Omomyinae (genera †*Navajovius*, †*Teilhardina*, †*Loveina*, †*Shoshonius*, †*Omomys*, †*Hemiacodon*, †*Washakius*, †*Microtarsius*, †*Chumashius*, †*Dyseolemur*, †*Hoanghonius*, †*Adapidium*), †Anaptomorphinae (genera †*Absarokius*, †*Tetonius*, †*Paratetonius*, †*Anaptomorphus*, †*Euryacodon*, †*Uintanius*, †*Yumanius*), †Microchoerinae (genera †*Necrolemur*, †*Microchoerus*, †*Nannopithec*, †*Periconodon*), and †Pseudolorisinae (genus †*Pseudoloris*).

The taxonomic status of the tarsiers is admittedly a problem. Hill himself says: "It is manifestly impossible . . . to describe at great length the anatomical characters of the Haplorhini . . . , for at almost every turn it would resolve itself into a case of *Tarsius* being an exception to the rule. Nevertheless, it must be recognized that *Tarsius* would also prove an exception to most of the rules had it been included with the lemurs . . ." (p. 2). Thus, as Hill notes in his section on the Haplorhini, *Tarsius* differs from the other haplorhines (monkeys, apes, man) in an impressive list of anatomical characters: a number of external features (of ear, tail, tarsus, tactile pads, dermatoglyphics and pedal digits, and in the number of nipples), numerous skeletal characters (of skull, scapula, manual digits, pelvis, leg, and foot), dentition, a variety of muscles (e.g., genioglossus, longissimus, short

manual flexors, femoral adductors, tibialis anterior, and pedal inter-ossei), structure of the brain (especially relating to cerebral cortex, thalamus, cerebellum, and innervation of extraocular muscles), as well as certain morphological details of the vascular system, pharynx, larynx, lungs, peritoneum, spleen, kidney, scrotum, uterus, and amnion.

This list, compiled by the reviewer in perusing Hill's text, is very revealing. For, although it lends no support to the once-current glib aphorismic pronouncement that *Tarsius* is "a lemur of the lemurs," it also demonstrates that *Tarsius* is anything but a simian or pithecoïd. In fact, it emphasizes the intermediacy of *Tarsius* with respect to the lemurs on the one hand and the simians on the other hand. It demonstrates, in the opinion of the reviewer, the logicity of a tripartite primary division of the order Primates, such as that proposed by Gadow in 1898 — into the suborders Lemuroidea, Tarsioidea, and Anthropeidea (or Pithecoidea) — rather than any bipartite primary division, whether it be into Strepsirhini and Haplorhini (Pocock, '18) or into Prosimii and Anthropeidea (Simpson, '45), or the like. Obviously, from this approach, if the tree-shrews are regarded as true Primates, a primary quadripartition is indicated, with the tupaïoids constituting a fourth suborder, the Tupaioidea. In the light of current taxonomic trends, this may be regarded as arrant splitting. To such an objection, the reviewer can only reply by paraphrase of the immortal words of Patrick Henry: "If this be taxonomic treason, make the most of it."

Two lists of references to literature are included in Volume II, for the Haplorhini *in toto* and for the Tarsioidea, respectively. These, particularly the latter, are more up-to-date, relative to publication date of the volume, than the list for the Strepsirhini in Volume I. That for the Haplorhini comprises 532 entries, the latest being dated 1952. Only three, however, are dated later than 1950. Seventy-six (14.3%) were published after 1940. A number of important publications, however, are not included. The list for Tarsioidea consists of 278 items. Of these, the latest entry is dated 1953, and 10 (3.6%) appeared after 1950. Thirty-four (12.2%) entries were published after 1940. Since many of the items in the Haplorhini list also deal with the Tarsioidea (although they are not repeated in the list for the latter), the bibliography on tarsiers is remarkably extensive.

The two volumes contain a number of factual errors inevitable to comprehensive works of this type. None, however, is of sufficient magnitude to merit special mention. The names of some authors are consistently distorted in both the literature lists and the text. Thus, for example, Bluntschli, Forster, Huber, Hubrecht, and Ruge are

incorrectly adorned with umlauts, as are Wood Jones, Tate Regan, and Elliot Smith with hyphens.

The general quality of the illustrations is very high; but some figures would have profited by more liberal labeling. Indeed, some are so bare of labels as almost to destroy their usefulness for anyone but the expert comparative anatomist. Finally, the publisher has done a first-rate job, the printing, reproduction of illustrations, and *format* of the volumes being of unusually high quality.

Taking everything into consideration, and particularly the magnitude of the task that he has undertaken, Hill has produced two timely volumes of great value. Probably no other single living individual could have done better, perhaps not as well. Certainly, all students of primates will be indebted to him. The reviewer, for one, anticipates with pleasure the promised volumes dealing with the various simian primates.

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BEGEGNUNGEN MIT DEM VORMENSCHEN. By G. H. R. von Koenigswald, pp. 230. \$3.50. Eugen Diederichs Verlag, Düsseldorf/Köln. 1955.

The fact that early man was geographically widespread has meant that current students of human evolution have frequently been deprived of the opportunity to examine at first hand the materials of their trade. Consequently, it is refreshing to have an account by one who includes among his experiences the excavation of important hominid specimens in Java, the extrication of controversial teeth in China, and paleontological trips to Choukoutien, South Africa, the Oldoway Valley, and elsewhere. These and other tales are recounted in this "paleontologist's journal," which has been modified for the non-technical reader.

The subject-matter is arranged geographically. Java is given the most space, with Africa, China and Europe following in that order. Although the fossils themselves are not extensively described, the sites and circumstances of discovery are often detailed colorfully and informatively. This seems a useful contribution, since the traditional texts deal briefly with such matters. For example, the Ngandong discoveries have been attributed to ter Haar, and to Oppenoorth and von Koenigswald. Actually, it appears that ter Haar found the site while admiring a sunset, native Mantris dug out the first skull, Oppenoorth then "discovered" it after it was sent to him in Bandung,

and certain other crania were later unearthed by ter Haar and von Koenigswald.

Among the highspots in the narrative are descriptions of von Koenigswald's scientific squabbles with Dubois, Black's last days at Peking, the intricacies of hunting "dragon teeth," the concealment of valuable fossils while a Japanese prisoner, and the plight of the author — penniless and jobless — on the verge of the Sangiran discoveries.

Von Koenigswald's views regarding the significance of the fossils he discusses are of particular interest. He extends the Neanderthal classification to encompass the Rhodesian and Hopefield skulls, the Soloensis material, and the bones from Swanscombe (a moderate type of Neanderthal which, like Steinheim, resembles modern man: p. 188). The author points out that although the Australopithecine may appear more human than simian, certain features of brain and dentition indicate that they should be classed nearer the apes. *Meganthropus* and the African man-apes probably go back to the same original form, but only the Javanese variety is in man's lineage. *Gigantopithecus* is the culmination of an extinct sideline. Although detailed phylogenies are premature, four successive stages may be delineated. These are represented by *Meganthropus*, *Pithecanthropus*, Solo-Neanderthal, and *sapiens*.

Professor von Koenigswald notes that Africa is an important culture center, but doubts that the southern tip of that continent is a likely spot for the inception of human development. He feels that good prospects for decisive fossil discoveries lie in the foreland of the Himalayas, and perhaps in Java.

There is a list of plates (20), of drawings (41), and a table of contents. Unfortunately, there is no index or bibliography.

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BOOK NOTES

THE PHYSICAL GROWTH OF CHILDREN: AN APPRAISAL OF STUDIES 1950-1955. By Wilton Marion Krogman. Monographs of the Society for Research in Child Development, Inc. Vol. XX, Serial No. 60, No. 1, 1955.

Professor Wilton Marion Krogman is a past master at assembling growth information, as witness his *Growth of Man* and his *Bibliography of Human Morphology*. The present red-jacketed monograph, with 222 references and 41 illustrations (largely reprinted from "Child Development") goes beyond the previous limits by summarizing information rather than merely clipping. As a result, the *Physical Growth of Children* can save a long stay with the abstracting and bibliographic journals, and reading some of the originals as well. It is a welcome addition.

Of the 91 pages, including bibliography and tables, but five constitute the "appraisal" guaranteed in the title. Here Dr. Krogman, troubled by the criticisms leveled at growth studies and at the charge that growth research often lacks a sense of problem, counters with a list of "aims" (p. 72).

Krogman's list of "aims" includes norms and their clinical applications. These aims are laudable, practical and realistic. Yet practical applications are not the same as theoretical problems and the future of any field lies in theory rather than today's utilization.

Many of the articles cited by Dr. Krogman are in themselves problem-oriented and provide a fair indication of the nature of growth research. These silently answer the criticisms and counter the charge by providing proof positive of where growth research is heading.

STANLEY MARION GARN

A STATISTICAL COMPARISON OF THE BODY TYPING METHODS OF HOOTON AND SHELDON. By C. Wesley Dupertuis and Irvin Emanuel. vi + 26 pp., Illus. WADC Technical Report 56-366. ASTIA document AD 97205 Wright Air Development Center WPAFB 1956.

As most readers of this journal know, Dr. Earnest A. Hooton, James V. Andrews and F. L. Stagg developed a system of body-typing

derived from, but deviating in certain respects from Sheldon's "somatotype" system. The present WADC technical report describing research initiated by H. T. E. Hertzberg, is concerned with the relationships between the two systems. Here, Hooton ratings were made by Hooton and Stagg, Sheldonian ratings by C. W. Dupertuis.

In general, Hooton's ratings differ from Sheldonian ratings by 0.51 (first component), -1.00 (second component) and 0.67 (third component). That the differences are only fairly constant is seen by the correlations between the two systems which hover about 0.85. Out of 500 individuals, identical ratings were given to but six subjects. Hooton's system of rating "dysplasia" proved totally unlike Sheldon's ($r = 0.05$).

In this terse report, no attempt is made to determine whether one system is inherently superior to the other. After all, there is no known way to prove that a subject is a 3.5 in mesomorphy instead of a 4.5. Looking at the zero order correlations between the first two components, Hooton ratings yielded an r of 0.20, and Dupertuis ratings (Sheldon system) resulted in a negative correlation of -0.23. Since fat and muscle do not appear to be correlated, when roentgenogrammetric measurements are used, empirical evidence at present does not favor one system over the other.

STANLEY M. GARN

THE LONGITUDINAL STUDY OF HUMAN DEVELOPMENT.
TECHNIQUES FOR APPRAISING DEVELOPMENTAL
STATUS AND PROGRESS. By Leland H. Stott. x + 115 pp.,
Illus. The Merrill-Palmer School, Detroit, Michigan. \$2.75.

This spiral-bound publication summarizes the system of grids, graphs, charts and schedules used and taught at the Merrill-Palmer School. Presented at an elementary level, the rationale behind the ratings, measurements and observations is incompletely spelled out. Of primary interest to us is the logarithmic age-equivalence graph used at the school (figs. 18-21). Though the area of physical growth is extensively discussed, it is not tied into the general picture of human development. With a rather naive approach to human genetics, with human variables treated as generally Gaussian, the good influence of the Merrill-Palmer School's physical anthropologist is barely felt.

STANLEY M. GARN

TECHNIQUES IN BLOOD GROUPING. By Ivor Dunsford and C. C. Bowley, with a preface by R. R. Race, pp. 250. C. C Thomas, Springfield. 1955.

The techniques of serology, including general procedures as well as the most detailed grouping methods, are covered in a very practical way in this book. It is a laboratory manual for the most part, but can as well give the general student an appreciation of what is involved in typing and the meaning of the tests which are used. A 37 page glossary and references selected with the descriptions of techniques combine to make this the best practical blood grouping manual now available.

F.P.T.

Proceedings of the 1954 Congress in Blood Transfusion. 5th Congress International De Transfusion Sanguine. Pp. 1191. L'Imprimerie Croutzet 70, Rue René-Boulanger, Paris (10°). 1955.

The sub-sections of the congress were under the headings of immunohematology, clinical problems, preparation and preservation blood and blood derivatives, and the organization of transfusion services. Of special interest to anthropologists are the numerous papers on the distribution of blood types in various populations as well as those on the new antigens, their occurrence and genetics. While many of the papers are in abstract form, the large number which are not makes this volume an excellent summary of the present status of blood group work. A section on sickle cell anemia and thalassemia is of special current interest. There are several papers on the relationship of blood groups to selection in man.

F.P.T.

POLYSACCHARIDES IN BIOLOGY. Edited by Georg F. Springer, pp. 271, \$5.00. The Josiah Macy, Jr. Foundation, New York. 1956.

This volume is a report of the transactions of the First Conference on Polysaccharides in Biology which met in April of 1955. The contents include papers, and lengthy verbatim discussion, on the subjects of nomenclature, problems of classification, bacterial polysaccharides and blood group substances. W. T. J. Morgan, leading the discussion on the blood group substances, gives a summary of his and related

work. His comments and data plus that of the other participants makes this section of the book—some 100 pages—a basic source on the nature of the blood group antigens. An understanding of this nature is essential if we are to ever to know *how* these now function and have functioned in becoming balanced polymorphic systems in human evolution.

F.P.T.

CELLULAR MECHANISMS IN DIFFERENTIATION AND GROWTH. Edited by Dorothea Rudnick, pp. 236, \$7.50. Princeton University Press, Princeton. 1956.

This book includes the papers contributed to the 14th Symposium of the Society for the Study of Development and Growth held at Amherst College in June of 1955. Intracellular events and intercellular relations were the general headings for the papers and problems of growth at the cellular level predominate. Billingham's paper on acquired tolerance of animals to foreign cells deals with several problems of interest in human immunology.

F.P.T.

KLAMATH PREHISTORY. THE PREHISTORY OF THE CULTURE OF THE KLAMATH LAKE AREA, OREGON. By L. S. Cressman, W. G. Haag and W. S. Laughlin. New Series, Vol. 46. Part 4; pp. 138. Transactions of the American Philosophical Society, Philadelphia. 1956.

This monograph describes the sites near Klamath Lake in Oregon in which several skulls and other human skeletal material from 18 individuals were found. These specimens some of considerable antiquity, are described in one section of the report by Laughlin and found to fit best with Great Basin material but contrasting with Oregon Coast or Willamette Valley remains.

F.P.T.

LEGG-CALVE-PERTHES SYNDROME AND RELATED OSTEOCHONDROSES OF YOUTH. By Charles W. Goff, in association with N. M. Shutkin and M. R. Hersey, pp. 322. Charles C Thomas, Springfield. 1954.

This is a definitive monograph on the LCPS which reflects the authors interest in both the clinical and anthropological aspects of this disorder. The relation to environment, racial frequencies, genetic information and basic growth data are well covered and integrated

into the clinical descriptions and diagnostic data. This book serves as an excellent example of the possible enrichment to an essentially clinical problem when a disorder is seen as occurring in man rather than in individual human beings; or in other words, what the approach of anthropology can add to the understanding of a human pathology.

F.P.T.

THE FUTURE OF ARID LANDS. Edited by Gilbert F. White, pp. 464, illus., 49, \$6.75. Publ. No. 43, American Association for the Advancement of Science, Washington. 1956.

The papers and recommendations resulting from the International Arid Lands Meetings held in 1955 are published in this book. No attention is given to the biological or evolutionary consequences of the distribution of the world's water but the data here serve as a background for studies of this sort and of general human ecology.

F.P.T.

THE BIOLOGICAL BASIS OF HUMAN FREEDOM. By Theodosius Dobzhansky, pp. 139. \$2.95. Columbia University Press, New York. 1956.

In this book Professor Dobzhansky highlights some of the philosophical implications of modern biology. This is done especially in terms of his interpretations of heredity, population genetics and evolution. The book is an expanded version of the Page-Barbour lectures given at the University of Virginia in 1954. While little technical detail is included in its pages, the text has considerable value in that it discusses the nature of man and his place in nature in general terms which can serve to introduce the reader to the study of anthropology.

F.P.T.

THE BIOCHEMISTRY AND PHYSIOLOGY OF BONE. Edited by Geoffrey H. Bourne, pp. 875, \$20.00. Academic Press, New York. 1956.

While some anthropologists of the past have considered bone as being almost inanimate building material quite unresponsive to en-

vironmental influences; others have regarded it only as the material going into a system of levers and struts to meet the mechanical requirements of locomotion. While there is some value to those points of view, the general understanding of the nature of bone has led to the idea that it is best regarded as an organ plastic and responsive to body requirements as well as being a fundamental body system in its own right. This book, containing 24 chapters written by 28 outstanding authors, deals largely with bone as an organ and gives very little attention to the final morphological features with which anthropologists have traditionally been concerned. However, the understanding of the morphology of bone depends upon the underlying processes that bring form and shape to bone. Anthropologists need study what is beneath the surface of bone as well as what is on it. A listing of a few selected chapters from this book can give an idea of its coverage and its suitability for students of bone morphology. The quality of the chapters and the book as a whole is superb.

G. H. Bell is the author of a chapter entitled, "Bone as a Mechanical Engineering Problem." There are several others dealing with the bone cells and the nature of the organic matrix, and these are followed by several on the nature of bone growth. Ernest Gardner on osteogenesis in the human embryo and fetus, H. B. Fell on skeletal development in tissue culture, H. A. Sissons chapter on the growth of bone followed by the chapter of Ham and Harris on the repair and transplantation of bone all combine to cover the subject of growth. All together these combine to form an outstanding reference book.

F.P.T.

IN SEARCH OF ADAM. By Herbert Wendt, translated by James Cleugh, pp. 540. Houghton Mifflin, Boston. 1956.

The author deals with the history of man's search for his ancestors and a knowledge of his place in nature. While Wendt is not a professional biologist, he does cover his subject in depth even though there is much detail with which a professional might quibble. The book is a current "Book-of-the-Month" selection and it can be expected that it will be widely read. While it would hardly serve as a student text book, its reading would aid immensely in giving the student a background to modern studies in evolution.

F.P.T.

INDEX

A BO genes in eastern Europe, distribution	577	Blood group genetical survey in West Nakanai, New Britain	275
Aborigines (Arnhem Land), hair of Australian	649	Blood factor in New York City Negroes, the Henshaw	445
Aborigine, the pterion in the Australian	225	Blood typing of human skull fragments from the Pleistocene, a	437
ACKERKNECHT, ERWIN H., AND HENRI VALLOIS. François Joseph Gall et sa collection. John D. Davis. Phrenology: Fad and science. A 19th century American crusade. Reviewed by Lucile E. Hoyme	334	<i>Book Notes</i>	675
Adaptive chin, the	119	<i>Book Notes</i>	341
Adolescence, at growth	120	<i>Book Notes</i>	537
Age, changes in lumbar vertebral body height with	35	Braincase of the infant pig, the role of the sutures in the growth of the	175
ALBRITTON, CLAUDE C. See Wendorf, Fred	126	<i>Brief Communication</i>	523
ALLBROOK, DAVID B. Changes in lumbar vertebral body height of age	35	<i>Brief Communication</i> : Henri Vallois. The pre-mousterian human mandible from Montmaurin	319
Amino-acids in the great apes, a chromatographic investigation of urinary	41	BRIGGS, L. CABOT. The stone age races of Northwest Africa. Reviewed by Charles E. Snow	325
ANDERSON, MARGARET, MARIE BLAIS AND WILLIAM T. GREEN. Growth of the normal foot during childhood and adolescence. Length of the foot, interrelations of foot, stature, and lower extremity as seen in serial records of children between 1-18 years of age	287	BURTON, A. C., AND O. G. EDHOLM. Man in a cold environment. Loren D. Carlson. Man in cold environment: A study in Physiology. Reviewed by Paul T. Baker	337
Anthropoid mesosterna, a comparison of human and	449	C AMERA, an evaluation of the Photo-metric	429
Anthropology, yearbook of	533	Capacity, external cranial volume as an estimate of cranial	661
Apes, a chromatographic investigation of urinary amino-acids in the	41	CARLSON, LOREN D. Man in cold environment. A study in Physiology	337
ARAMBOURG, C., AND P. BIBERSON. The fossil human remains from the Paleolithic site of Sidi Abderrahman (Morocco)	467	CATCHPOLE, H. R. See Wagenen, G. van	245
(Arnhem Land), hair of Australian aborigines	649	Changes in the human head and face in the third decade of life, dimensional	557
ASHLEY, G. T. A comparison of human and anthropoid mesosterna	449	Children and adults, skin reflectance studies in	101
ASHTON, E. H., AND S. ZUCKERMAN. The base of the skull in immature hominoids	611	Chin, the adaptive	119
Atlas of skeletal development of the knee, radiographic. A standard reference	327	CHOWN, BRUCE, AND MARION LEWIS. The blood group genes of the Cree Indians and the Eskimos of the Ungava district of Canada	215
Australian aborigines, hair of (Arnhem Land)	649	Chromatographic investigation of urinary amino-acids in the great apes	41
Australian aborigine, the pterion in the	225	CLARK, WILFRED EDWARD LE GROS, Viking Fund Medalist for 1955	309
B AER, MELVYN J. Dimensional changes in the human head and face in the third decade of life	557	Color grades, colorimetric estimation of the pigment concentration in hair of various	153
Base of the skull in immature hominoids, the	611	Colorimetric estimation of the pigment concentration in hair of various color grades	153
Begegnungen mit dem Vormenschen	673	(Comparative anatomy and taxonomy). I. Strepsirhini. II. Haplorhini: Tarsiodea, primates	668
BIBERSON, P. See Arambourg, C.	467	Comparison of human and anthropoid mesosterna, a	449
BIRDSELL, JOSEPH B. See Dobzhansky, Theodosius	665	Concurrent fat loss and fat gain	497
BLAIS, MARIE. See Anderson, Margaret	287	Cranial shape, the measurement of	59
Blood group genes of the Cree Indians and the Eskimos of the Ungava district of Canada	215	Cranial volume as an estimate of capacity, external	661
		Craniology, an evaluation of Polynesian	405
		CRARY, D. D. See Sawin, P. B.	625
		CRAWFORD, MARY R. See Garn, Stanley Marion	101

- Cree Indians and the Eskimos of the Ungava district of Canada, the blood genes of the 215
- Crests, sagittal lines and 523
- Culture and human fertility. A study of the relation of cultural conditions to fertility in now industrial and transitional societies. *Reviewed by* Clyde Kluckhohn 527
- D**ENTAL features among the native peoples of the Pacific, shovel-shaped incisors and a few other
- Developmental microscopic defects in the teeth of subhuman primates 193
- Digits of the human foot, radiological studies of variations in the segmentation and ossification of the. I. Variation in the number of phalanges and centers of ossification of the toes 1
- Dimensional changes in the human head and face in the third decade of life 557
- Distribution of ABO genes in eastern Europe 577
- DOBZHANSKY, THEODOSIUS. Evolution, genetics, and man. *Reviewed by* Joseph B. Birdsall 665
- DOBZHANSKY, THEODOSIUS. See Gartler, Stanley M. 41
- DRENNAN, M. R. Note on the morphological status of the Swanscombe and Fontéchevade skulls 73
- DU BRUL, LLOYD E., AND HARRY SICHER. The adaptive chin. *Reviewed by* Wilfrid T. Dempster 119
- DUGGINS, OLIVER H. See Trotter, Mildred 649
- E**DHOLM, O. G., AND A. C. BURTON. Man in a cold environment 337
- Embryos as an approach to basic principles of mammalian growth, quantitative racial differences in ossification pattern of the vertebrae of. XVI. Morphogenetic studies of the rabbit 625
- Eskimos of the Ungava district of Canada, the blood group genes of the Cree Indians and the 215
- Europe, distribution of ABO genes in eastern 557
- Evaluation of the Photo-metric camera, an 429
- Evaluation of Polynesian craniology, an Evidence of random genetic drift in human populations, on the 541
- External cranial volume as an estimate of cranial capacity 661
- Evolution, genetics and man 665
- Estimation of skeleton weight in the living 589
- F**ACE in the third decade of life, dimensional changes in the human head and 557
- Fad and science. A 19th century American crusade: Phrenology 334
- Fat loss and fat gain, concurrent 497
- Fertility, culture and human. A study of the relation of cultural conditions to fertility in non-industrial and transitional societies 527
- Finnish students, on the frequency of the missing peg-shaped maxillary lateral incisor among 491
- FIRSCHER, LESTER I. See Gartler, Stanley M. 41
- Fontéchevade skulls, note on the morphological status of the Swanscombe and 73
- Foot, radiological studies of variations in the segmentation and ossification of the digits of the human. I. Variation in the number of phalanges and centers of ossification of the toes 1
- Foramina in the races of man, multiple infraorbital, ethmoidal, and mental 85
- Forgery, the Piltdown 124
- Fossil human remains from the Paleolithic site of Sidi Abderrahman (Morocco), the 467
- Fragments from the Pleistocene, a blood typing of human skull 437
- G**AIN, concurrent fat loss and fat 497
- GARN, STANLEY M., AND RICHARD W. YOUNG. Concurrent fat loss and fat gain 497
- GARN, STANLEY MARION, SAMUEL SELBY AND MARY R. CRAWFORD. Skin reflectance studies in children and adults 101
- GARTLER, STANLEY M., I. LESTER FIRSCHER AND THEODOSIUS DOBZHANSKY. A chromatographic investigation of urinary amino-acids in the great apes 41
- Genes in eastern Europe, distribution of ABO 577
- Genes of the Cree Indians and the Eskimos of the Ungava district of Canada, the blood group 215
- Genetics, and man, evolution 665
- Genetical survey in West Nakanai, New Britain, a blood group 275
- Genetic drift in human populations, on the evidence of random 541
- Geochronology, with special reference to Southwestern United States 122
- GILES, EUGENE. See Hunt, Edward, Jr. 429
- GLASS, BENTLEY. On the evidence of random genetic drift in human populations 541
- GRAYDON, J. J. See Simmons, R. T. 275
- GREEN, WILLIAM T. See Anderson, Margaret 287
- Growth at adolescence 120
- Growth of the normal foot during childhood and adolescence. Length of the foot interrelations of foot, stature and lower extremity as seen in serial records of children between 1-18 years of age 287
- H**AIR of Australian aborigines (Arnhem Land) 649
- HANNA, L. BERTRAM. Colorimetric estimation of the pigment concentration in hair of various color grades 153
- Head and face in the third decade of life, dimensional changes in the human 557
- Henshaw blood factor in New York City Negroes, the 445
- Height with age, changes in the lumbar vertebral body 35

- HILL, W. C. OSMAN. Primates (comparative anatomy and taxonomy). I. Strepsirhini. II. Haplorhini: Tarsiodea. *Reviewed by* William L. Straus, Jr. 668
- HOERRE, L. NORMAND. See Pyle, S. Idell 327
- Hominoids, the base of the skull in immature 611
- Human and anthropoid mesosterna, a comparison of 449
- Human foot, radiological studies of variation in the segmentation and ossification of the digits of the. Variation in length of the digit segments correlated with difference of segmentation and ossification of the toes 129
- Human foot, radiological studies of variations in the segmentation and ossification of the digits of the. I. Variation in the number of phalanges and centers of ossification of the toes 1
- HUNT, EDWARD E., JR., AND EUGENE GILES. An evaluation of the Photo-metric camera 429
- Human head and face in the third decade of life, dimensional changes in the 557
- Human populations, on the evidence of random genetic 541
- Human remains from the Paleolithic site of Sidi Abderrahman (Morocco), the fossil 467
- Human skull fragments from the Pleistocene, a blood typing of 437
- I**NCISORS and a few other dental features among the native peoples of the Pacific, shovel-shaped 505
- Infraorbital, ethmoidal, and mental foramina in the races of man, multiple 85
- J**ORGENSEN, JORGEN BALSLEV, AND FLEMMING QUADE. External cranial volume as an estimate of cranial capacity 661
- K**NEE, radiographic atlas of skeletal development of the. A standard reference 327
- KOENIGSWALD, G. H. R. VON. Begegnungen mit dem Vormenschen 673
- KREIGER, ALEX D. See Wendorf, Fred 126
- L**ENGTH of the foot interrelations of foot, stature and lower extremity as seen in serial record of children between 1-18 years of age. Growth of the normal foot during childhood and adolescence 287
- LEWIS, MARION. See Chown, Bruce 215
- Life, dimensional changes in the human head and face in the third decade of 557
- Lines and crests, sagittal 523
- Living, estimation of skeleton weight in the 589
- LORIMER, FRANK. Culture and human fertility. A study of the relation of cultural conditions to fertility in non-industrial and transitional societies. *Revived by* Clyde Kluckhohn 527
- Loss and fat gain, concurrent 497
- Lumbar vertebral body with age, changes in lumbar 35
- M**AMMALIAN growth, quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of. XVI. Morphogenetic studies of the rabbit 625
- Man, evolution, genetics, and 665
- Man, multiple infraorbital, ethmoidal, and mental foramina in the races of man 85
- MANUILA, A. Distribution of ABO genes in eastern Europe 577
- MARSHALL, DONALD STANLEY, AND CHARLES ERNEST SNOW. An evaluation of Polynesian craniology 405
- Measurement of cranial shape 59
- Medalist for 1955, Viking Fund 309
- MEDNICK, LOIS W., AND S. L. WASHBURN. The role of the sutures in the growth of the braincase of the infant pig 175
- Memorial: Pompeo Benjamin Candela 319
- Mental foramina in the races of man, multiple infraorbital, ethmoidal, and 85
- MERZ, ANN L., MILDRED TROTTER AND ROY R. PETERSON. Estimation of skeleton weight in the living 589
- Mesosterna, a comparison of human and anthropoid 449
- Microscopic defects in the teeth of subhuman primates, developmental 193
- Midland discovery. With a description of the skull 126
- (Morocco), the fossil human remains from the Paleolithic site of Sidi Abderrahman 467
- Morphogenetic studies of the rabbit. XVI. Quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth 625
- Morphological status of the Swanscombe and Fontéchevade skulls, note on 73
- Multiple infraorbital, ethmoidal, and mental foramina in the races of man 85
- MURPHY, THOMAS. The pterion in the Australian aborigine 225
- N**ATIVE peoples of the Pacific, shovel-shaped incisors and a few other dental features among the 505
- Negroes, the Henshaw blood factor in New York City 415
- New York City Negroes, the Henshaw blood factor in 415
- Non-industrial and transitional societies, a study of the relation of cultural conditions to fertility in. Culture and human fertility 527
- Northwest Africa, stone age races of 325
- Note on the morphological status of the Swanscombe and Fontéchevade skulls 73
- O**N the frequency of the missing and peg-shaped maxillary lateral incisors among Finnish students 491

- Ossification of the digits of the human foot, radiological studies of variations in the segmentation and. I. Variation in the number of phalanges and centers of ossification of the toes 1
- Ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth, quantitative racial. Morphogenetic studies of the rabbit 625
- OTTEN, CHARLOTTE M. See Thieme, Fred P. 437
- PACIFIC**, shovel-shaped incisors and a few other dental features among the native peoples of the 505
- Paleolithic site of Sidi Abderrahman (Morocco), the fossil human remains from the 467
- Peoples of the Pacific, shovel-shaped incisors and a few other dental features among the native 505
- PETERSON, ROY R. See Merz, Ann L. 589
- Photo-metric camera, an evaluation of the 429
- Phrenology: Fad and science. A 19th century American crusade 334
- Physical growth of the rhesus monkey (*Macaca mulatta*) 245
- Pigment concentration in hair of various color grades, colorimetric estimation of the 153
- Pig, the role of the sutures in the growth of the braincase of the infant pig 175
- Pittdown forgery, the 124
- Pleistocene, a blood typing of human skull fragments from the 437
- POLLITZER, WILLIAM S. The Henshaw blood factor in New York City Negroes 445
- Polynesian craniology, an evolution of Populations, on the evidence of random genetic drift in 541
- Primates (comparative anatomy and taxonomy). I. Strepsirhini. II. Haplorhini: Tarsioides 668
- Primates, developmental microscopic defects in the teeth of subhuman 193
- Pterion in the Australian aborigine 225
- PYLE, S. IDELL, AND NORMAND L. HOERR. Radiographic atlas of skeletal development of the knee. A standard reference. *Reviewed by* Stanley M. Garn 327
- QUAADE**, FLEMMING. See Jørgensen, Jørgen Balslev 661
- Quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth, XVI. Morphogenetic studies of the rabbit 625
- RABBIT**, morphogenetic studies of the. XVI. Quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth 625
- Racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth. Morphogenetic studies of the rabbit 625
- Races of man, multiple infraorbital, ethmoidal, and mental foramina in the 85
- Radiographic atlas of skeletal development of the knee. A standard reference 327
- Radiological studies of variations in the segmentation and ossification of the digits of the human foot. I. Variation in the number of phalanges and centers of ossification of the toes 1
- Radiological studies of variation in the segmentation and ossification of the digits of the human foot. Variation in length of the digit segments correlated with difference of segmentation and ossification of the toes 129
- RANTANEN, AIMO V. On the frequency of the missing and peg-shaped maxillary lateral incisor among Finnish students 491
- Reflectance studies in children and adults, skin 101
- Rhesus monkey, physical growth of the (*Macaca mulatta*) 245
- RIESENFIELD, ALPHONSE. Multiple infraorbital, ethmoidal, and mental foramina in the races of man 85
- RIESENFIELD, ALPHONSE. Shovel-shaped incisors and a few other dental features among the native peoples of the Pacific 505
- Role of the sutures in the growth of the braincase of the infant pig 175
- SAGITTAL** lines and crests 523
- SAWIN, P. B., AND D. D. CRARY. Morphogenetic studies of the rabbit. XVI. Quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth 625
- SCHUMAN, ELIHU LEON, AND REIDAR FAUSKE SOGNAES. Developmental microscopic defects in the teeth of subhuman primates 193
- Segmentation and ossification of the digits of the human foot, radiological studies of variations in the. I. Variation in the number of phalanges and centers of ossification of the toes 1
- SELBY, SAMUEL. See Garn, Stanley Marion 101
- SEMPLE, N. M. See Simmons, R. T. 275
- SETZLER, FRANK M. See Trotter, Mildred 649
- Shape, the measurement of cranial Shovel-shaped incisors and a few other dental features among the native peoples of the Pacific 505
- SICHLER, HARRY. See Du Brul, E. Lloyd 119
- Sidi Abderrahman (Morocco), the fossil human remains from the Paleolithic site of 467
- SIMMONS, R. T., J. J. GRAYDON, N. M. SEMPLE AND D. R. SWINDLER. A blood group genetical survey in West Nakanai, New Britain 275
- Skeleton weight in the living, estimation of 589
- Skin reflectance studies in children and adults 101

- Skull fragments from the Pleistocene, a blood typing of human 437
- Skull in immature hominoids, the base of the 611
- Skulls, note on the morphological status of the Swanscombe and Fontéchevade 73
- SMILEY, T. L. Geochronology, with special reference to Southwestern United States. *Reviewed by Erik K. Reed* 122
- SNOW, CHARLES ERNEST. See Marshall, Donald Stanley 405
- Societies, a study of the relation of cultural conditions to fertility in non-industrial and transitional. Culture and human fertility 527
- SOGNNAES, REIDAR FAUSKE. See Schuman, Elihu Leon 193
- Southwestern United States, geochronology, with special reference to 122
- Stone age races of Northwest Africa 325
- Studies in children and adults, skin reflectance 101
- Studies of the rabbit, morphogenetic. XVI. Quantitative racial differences in ossification pattern of the vertebrae of embryos as an approach to basic principles of mammalian growth 625
- Study of the relation of cultural conditions to fertility in non-industrial and transitional societies, a. Culture and human fertility 527
- Subhuman primates, developmental microscopic defects in the teeth of SUTTON, H. ELDON. See Thieme, Fred P. 437
- Sutures in the growth of the braincase of the infant pig, the role of the 175
- Swanscombe and Fontéchevade skulls, note on the morphological status of the 85
- SWINDLER, D. R. See Simmons, R. T. 275
- TANNER, J. M. Growth at adolescence. *Reviewed by Stanley Marion Garn* 120
- Taxonomy). I. Strepsirhini. II. Haplorhini: Tarsioidea, primates (comparative anatomy and 668
- The adaptive chin 119
- The American Association of Physical Anthropologists. Proceedings 349
- Teeth of subhuman primates, developmental microscopic defects in the 193
- THIEME, FRED P., CHARLOTTE M. OTTEN AND H. ELDON SUTTON. A blood typing of human skull fragments from the Pleistocene 437
- THOMAS, WILLIAM L., JR. Yearbook of Anthropology. *Reviewed by Bernice A. Kaplan* 533
- Transitional societies, a study of the relation of cultural conditions to fertility in non-industrial and. Culture and human fertility 527
- TROTTER, MILDRED, OLIVER H. DUGGINS AND FRANK M. SETZLER. Hair of Australian aborigines (Arnhem Land) 649
- TROTTER, MILDRED. See Merz, Ann L. 589
- UNGAVA district of Canada, the blood group genes of the Cree Indians and the Eskimos of the 215
- Urinary amino-acids in the great apes, a chromatographic investigation of 41
- VALLOIS, HENRI. See Ackerknecht, Erwin H. 334
- Variation in length of the digit segments correlated with difference of segmentation and ossification of the toes. Radiological studies of variation in the segmentation and ossification of the digits of the human foot 129
- VENNING, P. Radiological studies of variation in the segmentation and ossification of the digits of the human foot. Variation in length of the digit segments correlated with difference of segmentation and ossification of the toes 129
- VENNING, P. Radiological studies of variations in the segmentation and ossification of the digits of the human foot. I. Variation in the number of phalanges and centers of ossification of the toes 1
- Vertebral body height with age, changes in lumbar 35
- Vertebrae of embryos as an approach to basic principles of mammalian growth, quantitative racial differences in ossification pattern of the. Morphogenetic studies of the rabbit. XVI. 625
- Viking Fund medalist for 1955 309
- Volume as an estimate of cranial capacity, external cranial 661
- WAGENEN, G. VAN, AND H. R. CATCHPOLE. Physical growth of the rhesus monkey (*Macaca mulatta*) 245
- WASHBURN, S. L. See Mednick, Lois W. 153
- Weight in the living, estimation of skeleton 589
- WEINER, J. S. The Piltdown forgery. *Reviewed by Erik K. Reed* 122
- WENDORF, FRED, ALEX D. KRIEGER AND CLAUDE C. ALBRITTON. With a description of the skull by T. D. Stewart. The Midland discovery. *Reviewed by Robert F. Heiser* 126
- West Nakanai, New Britain, a blood group, genetical survey in 275
- YEARBOOK of Anthropology 533
- YOUNG, RICHARD W. See Garn, Stanley M. 497
- YOUNG, RICHARD W. The measurement of cranial shape 59
- ZUCKERMAN, S. Sagittal lines and crests 523
- ZUCKERMAN, S. See Ashton, E. H. 611

